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AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XXXIV.—*The Apertures of Coronas, in Relation to the Number of Nuclei and their Size;* by C. BARUS.

1. *Introductory.*—Throughout my work with coronas, I have relied chiefly upon the color sequences, and have taken the data for numbers and sizes of cloud particles (a fixed degree of supersaturation presupposed) from the tables given elsewhere.* When apertures were measured this was done chiefly for the identification of the series to which the corona belongs. There is no doubt, however, that an expression for the diameters of particles in terms of the aperture of the coronas would be a great and immediate convenience, particularly as facility in using the color sequences is apt to be lost, unless one is at work with them continually. Apart from this the colors represent steps of progress, while the apertures should be continuously, even if irregularly, variable. The purpose is then to find under what conditions the discrepancies of aperture may be reduced to a minimum.

If the supersaturation is constant throughout, the diameters of cloud particles and their distance apart will in general be proportional quantities. Let m be the grams of water precipitated, n the number of particles per cubic centimeter, $D = n^{-1/3}$ their distance apart, d the diameter of each, s the aperture of the corona. If, therefore, for normal coronas $d = as$, where a is a constant found by purely optical experiments,

$$n = (6m/\pi a^3)s^3 = (6m/\pi)/d^3 = 1/D^3, \text{ and } d = D(\pi/6m)^{1/3}$$

But it is doubtful if these equations are true even for normal coronas, and they must certainly be a very crude approxima-

* This Journal (4), xiii, p. 81, 1902; Phil. Mag. (6), iv, p. 26, 1902; cf. Structure of the Nucleus, Smithsonian Contributions, 1902, chapter 3.

tion for coronas of the higher orders, where d and D are possibly both implicated in producing coronal effects. If one builds up a system of glass plates each sprinkled with lycopodium particles, the diffraction pattern which is finely annular for a single plate, is a mere blur for ten plates placed within a linear foot for instance, without changing the aperture appreciably. If the source of light and the eye are both distant, the coronas gradually lose sharpness and soon cease to be measurable as the number of plates increases. This indicates the nicety of distribution and the equality of diameter that must be met with in case of cloud particles, but it leaves the question open whether the distance apart of particles is not from the outset a consideration.

What is further menacing is the distortion produced by spherical and cylindrical vessels, the surfaces of which are rarely quite concentric. In my work with globes, I assumed that if the annuli showed no elliptic distortion and were small in aperture as compared with the aperture of the globe, distortion could be neglected. It is questionable, however, if this observation is vouched for, since the apertures of coronas are peculiarly sensitive to refraction, particularly when the distances of eye and source from the receiver are purposely chosen large. § 3.

Again, the quantity m is dependent on temperature to a marked degree. It is necessary, therefore, to refer coronas to a standard temperature as well as to a given degree of supersaturation, and the correction is particularly important if the coronas are to be used in estimating the number of particles. § 6.

Finally, the ratio of densities before and after exhaustion is a seriously difficult datum to determine, for it depends on the degree to which adiabatic conditions have been attained. It is here that the work is liable to be discrepant. Hence a determination of apertures has an ulterior value, for it is not improbable that the two series of results will *mutually interpret each other*. The present paper bears out this surmise. §7.

2. *Apparatus and preliminary results.*—The tables investigated contain a preliminary survey* of the sequence of coronas, their apertures (s) and the number of particles (n per cub. cm.) of specified diameter (d) encountered. The data for diameter and number, d and n, are taken from my work on successive exhaustion, where the experiments are largely non-optical, and they are compared with the corresponding data, d' and n', which follow from measurements of aperture. The eye and source of light are distant 1 and 3 meters, respectively, from the conden-

*The tables are withdrawn for brevity, since the data used in this paper are sufficiently given in the chart.

sation chamber between them. This was here a tall cylindrical vessel of as clear glass as possible, 50^{cm} long and 13^{cm} in diameter. The observations were made parallel to the axis, absence of distortion being assumed for the axial plane, an assumption which was here justified by a comparison with plate glass apparatus, though the latter was not quite large enough for the complete survey. The method of work was otherwise the same as that described in my earlier papers.

The constants of the goniometer were determined so that $s'd' = \cdot0023$ and $n' = 120\ s'^3$ for the mean temperature 20° C. Phosphorus nuclei were used throughout. The pressure decrement on exhaustion was always $\delta p = 17^{cm}$.

The results of the tables are given in the accompanying chart, in which the old results for diameter and aperture, d and s, are laid off horizontally, the new results d' and s', computed as stated from the observed apertures, vertically. The discrepancy of the two sets of data is marked and the curves all show sustained periodicity.

3. *Diameter of cloud particle.*—The variations of d and d' are on the average $\delta d = 1{\cdot}4\ \delta d'$ from curve 4, and $\delta d = 1{\cdot}6\ \delta d'$ from curve 5. In other words, the diameters obtained for coronas by computation from the conditions of successive exhaustion are about 1·5 times larger than the same data estimated directly from the apertures of the coronas.

Moreover the new values of diameter, d', show a curious periodicity which must be peculiar to them, since the old values from the manner in which they were obtained (geometric progression) can not be periodic. There is accelerated increase of diameter toward the crimson types, Nos. 9 and 14, and a falling off which may even be a retrogression toward the green types, Nos. 4–5, 11–12, 15–16, these being respectively the crests and troughs of the wave. The undulation continues even beyond this, but it is then difficult to identify it when the annuli become crowded into the normal coronas. The results are similar in all the experiments. Moreover the same undulatory line was encountered both for phosphorus and for water nuclei, with maxima at the 9th and 14th coronas, when a different vessel (aspirator, 32^{cm} high, 22^{cm} in diameter) was used; and the ratio, $\delta d = 1{\cdot}3\ \delta d'$, was distinctly smaller for this case, showing the marked influence of distortion due to the vessel. The same ratio (1·3) was found in connection with the preliminary experiments with plate glass apparatus (curve 3).

4. *Nucleation.*—Since nd^3 is constant, remarks of the same general character may be made for the nucleation, n, except that the discrepancy will be reciprocal in character and enormously exaggerated. If on the average $d = 1{\cdot}5\ d'$, $n' = 3{\cdot}4\ n$; if $d = 1{\cdot}3\ d'$, $n' = 2{\cdot}2\ n$, but the undulations have now become

so sweeping that a ratio can only be inferred for the small coronas.

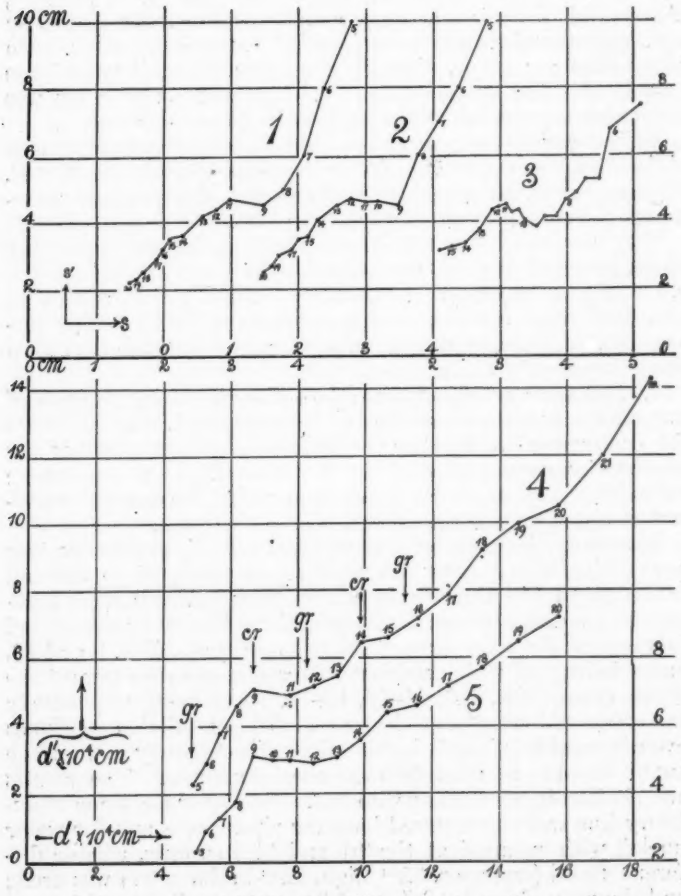


Chart.—Curves 1 and 2, relations of apertures computed from successive exhaustions (s) and directly measured (s'). Tall cylindrical receiver, 13^{cm} in diameter. Curve 3, the same for plate glass apparatus 20^{cm} deep. Coronas were difficult to place. Order numbers, z, attached to curves.

Curves 4 and 5, relation of diameter of fog particle computed from successive exhaustions (d), and from measurements of aperture (d'), both given in centimeters. Tall cylindrical receiver. The types of coronas are marked *gr* (green centered), *cr* (white-crimson centered). Curve 5 dropped ·0002^{cm}. Small dots refer to a special series. Numbers on the curves show the orders (z) of the successive coronas.

5. *Cause of periodicity.*—If one inquires into the cause of the periodic discrepancies, it appears that the crimson coronas are too small or else the green coronas too large, for the data computed from exhaustions cannot be periodic. The former being white-centered with a diffuse red margin, it is impossible to mistake the outside edge of the first ring for the inside edge. The blue-green coronas, however, show a uniformly colored disc, and here the first ring may be of the same color as the disc and the corona would then be measured to the outside margin of the first ring. From this point of view only the crimson coronas are adapted for measurement, and both curves 4 and 5 would then give $d = 1{\cdot}3\ d'$ and $n' = 2{\cdot}2\ n$. Since the curves actually give evidence of diminishing aperture while the droplets certainly decrease in size, this explanation is plausible, though it does not agree well with the evidence from normal coronas. The red and crimson coronas are the only ones which retain the white center, and the phenomenon may in so far be regarded as similar to the case of normal coronas.

6. *Effect of temperature.*—The explanation of the discrepancy between d and d' (computed from exhaustions and measured from apertures, respectively) reduces in the most favorable case to $d = 1{\cdot}3\ d'$, and for this two explanations must be examined. Supposing that one does not inadvertently measure into a ring, the value of m which enters into the computation of d is very variable with temperature. For $\delta p = 17^{cm}$, for instance,

at 10°,	$m = {\cdot}42 \times 10^{-6}$	grams per cub. cm.,
20°,	${\cdot}76 \times 10^{-6}$	" " "
30°,	$1{\cdot}28 \times 10^{-6}$	" " "

Since d varies as $m^{-1/3}$, for the same nucleation, the values of d at 10°, 20°, 30°, will be in the ratio of ·75, ·96, 1·09, respectively, and the coronas will be in the same degree smaller. Between 20° and 30° this amounts to 2 per cent of the value at 20°. Hence to bring the values of d computed from successive exhaustion into coincidence with the data computed from apertures, would require a temperature excess of over 15°, which is out of the question.

7. *Pressure decrement.*—As none of the explanations are satisfactory, light of a different character may be thrown upon the discrepancy by computing the density ratio, y', of the gas after and before exhaustion, corresponding to the observed values, s'. Since if n is the nucleation, z the order of the corona in a geometric series, b the coefficient of time loss, t the time interval between exhaustions,

$$\log n = z(1 + bt) \log y$$

the equation corresponding to a different exhaustion ratio would be

$$\log n' = z(1+bt)\log y'$$

if the same corona, z, and time interval, t, is implied.

Hence $\delta(\log n) = \delta(\log y)$ while $n = (6m/\pi a^2)s^3 = 120s^3$. Therefore $\log y'/\log y = (\log A + 3\log s')/(\log A + 3\log s)$.

The computed valnes $s = a\sqrt[3]{n\pi/6m}$ are given in the chart, curves 1, 2, 3. From the latter for $s = 5{\cdot}0$, $s' = 8{\cdot}0$ to $9{\cdot}0^{cm}$. Hence

$$\begin{aligned} s' &= 8, & y' &= {\cdot}807, \\ s' &= 9, & y' &= {\cdot}804, \end{aligned}$$

whereas $y = {\cdot}819$ was the value computed in my work on coronas* for the exhaustion 76–58^{cm}.

Since roughly $y = (p/p_0)^{1/\gamma}$, where $p = 76$ and $\gamma = 1{\cdot}4$, the following values of δp obtain:

$$\begin{aligned} s &= 5{\cdot}0^{cm}, & \delta p &= 18{\cdot}0^{cm}, \\ s' &= 8{\cdot}0 & & 19{\cdot}1 \\ s' &= 9{\cdot}0 & & 19{\cdot}4 \end{aligned}$$

Thus if the pressure decrement on exhaustion had been taken 1^{cm} higher than the observed value, the apertures computed from successive exhaustions in the former memoir would agree with the average apertures directly measured in the present paper. Observationally this is out of the question, but it is nevertheless difficult to know just what pressure is effective in the adiabatically cooled receiver (cf. Structure of the Nucleus, p. 38, § 16), since neither the isothermal nor the adiabatic conditions will rigorously suffice. The memoir shows that isothermally $y = {\cdot}764$; adiabatically $y = {\cdot}825$; adiabatically with allowance for condensed water $y = {\cdot}819$, as already specified. The present aperture data demand $y = {\cdot}805$, which is even nearer to the isothermal y than the value taken.

Incidentally one may note the precision with which y must be entered or the pressure difference determined, if the observations are to be sufficiently close to admit of a computation of d and n. In other words, it is probable, that the ratio y may be determined with greater accuracy from the successive apertures as a whole, notwithstanding their periodic character, than by direct measurement. This is what I meant by stating that the two sets of observations would probably sustain each other, for nobody would be justified in using the apertures of abnormal coronas, unless such use was suggested and guided by independent evidence. My own conviction is that $n' = 2{\cdot}2\,n$ may now be accepted with confidence.

8. *Summary.*—The result of this paper is then favorable to the use of the apertures of coronas in place of the colors of the annuli, for estimating the number of particles corresponding to

* Structure of the Nucleus, chapters 3 and 4, this Journal, xiii, p. 83, 86.

a given degree of supersaturation at a given temperature. Full allowance must, however, be made for the occurrence of *periodic variations* of aperture in relation to the diameter of the fog particles; in other words, a given aperture is only of value when qualified by the type of corona (whether of the crimson or green order) to which the aperture belongs. Thus it will not in any case be possible to dispense completely with the color pattern. It is with the object of finding these corrections systematically that I have recently begun a series of experiments with a new form of plate glass apparatus and shall then refer to other developments. Homogeneous light, though in many respects desirable, gives effects so faint as to be useless in practice.

With the above data I am able to make an independent estimate of the number of particles in the saturated phosphorus emanation. The number found for the first fog of the series was (Phil. Mag. (6), iv, p. 25, 1902) $n = 83{,}000$; since $n' = 2{\cdot}2\,n$, $n' = 183{,}000$ particles per cub. cm. Now the density ratio before and after exhaustion is y, so that $1-y$ is the volume of saturated emanation added. As this has passed directly and slowly over excess of phosphorus, it must be very nearly saturated, becoming diluted on mixture with the dust free air of the receiver. Hence if n_0 particles per cub. cm. correspond to saturation, $n_0(1-y) = n' = 183{,}000$; or $n_0 = 10^6$. There must, therefore, be at least a million nuclei per cub. cm. of the air immediately in contact with a surface of phosphorus. The value following from my electrometer work was $n_0 = 2\times10^6$. The two methods are absolutely distinct but lead to data of the same order. It is because of the general reasonableness of the data which have followed from my simple hypothesis throughout a very wide territory of observation that I have felt bound to adhere to it, in spite of the more startling corpuscular explanations which might be adduced.

Brown University, Providence, R. I.

Art. XXXV.—*Klamath Mountain Section, California;* by J. S. Diller.

Introduction.

The purpose of this general review of the sedimentary rocks of the Klamath Mountains is to render more definite the geological horizons to which a large portion of them belong, and to give their general distribution and structural relations.

A preliminary geologic map of the Klamath Mountains was issued by the U. S. Geological Survey* in 1894, upon which all the rocks below the Cretaceous were grouped under one color. Fairbanks, Smith, Anderson and Hershey have since added much to the available knowledge of the region, but excepting part of Shasta County, where fossils are abundant, the geological age of the horizons has not been definitely determined.

Last summer, accompanied by Dr. T. W. Stanton and James Storrs, the author made a trip across the southern end of the Klamath Mountains to Mad River† and supplemented collections made by him in that region at various times during the last decade.

The formations of the Klamath Mountains for the most part trend northwesterly in approximately parallel belts from the northern end of the Sacramento Valley to the coast between the mouth of Red Wood Creek in California and Rogue River in Oregon. It is evident that the lines of deformation which determined the trend of outcrop follow the same course and are in the main approximately parallel to those of the Sierra Nevada. These belts along the western portion of the Klamath Mountains are quite regular, but nearer the mountain center they become very irregular owing to the presence of numerous masses of igneous rocks. Most of our attention was given to the sedimentary rocks, more or less fossiliferous, which may be grouped in the following categories: Pre-Devonian, Devonian, Carboniferous, Triassic, Jurassic, Cretaceous, Miocene, Pliocene and Pleistocene.

The pre-Devonian, Devonian and Carboniferous rocks with associated igneous masses form the bulk of the Klamath Mountains, and they occur in two belts which may be designated

* Fourteenth Annual Report, plate xlv.

† In this work the "Rough Geological Map of Trinity County," dated January 16, 1901, furnished in manuscript by Mr. Hershey, was found very useful. It gives a clear general idea of the areal distribution of important terranes. This map was noticed also in U. S. Geological Survey Bulletin 196, page 63. On page 9 of the same bulletin there is an outline map of the Klamath Mountains to which reference may be made for the relative position of localities mentioned in this paper.

the southwestern and northeastern. The southwestern belt embraces South Fork Mountain and all the country bordering the Salmon Mountains and Bully Choop upon the southwest, while the northeastern belt, beginning in the Bully Choop and Salmon Mountains, extends northeast to the Great Bend of Pit River. It is of importance to note that in each belt the oldest rocks lie upon the southwest, decreasing in age to the northeast, and in the northeastern belt the succession extends up through the Triassic, Jurassic and Cretaceous.

Pre-Devonian.

Southwestern belt of schists.—The oldest rocks of the region are schists,* of which the southwestern belt forms North Yallo Bally and South Fork Mountain and may be traced from the western part of Tehama County northwest between the South Fork of Trinity and Mad River to the coast at the mouth of Red Wood Creek, while the northeastern belt passes through Bully Choop and Salmon Mountains.

The principal rock of South Fork Mountain is a gray or greenish gray, more or less silky, mica-schist in which the mica is sericite. Although in well defined folia and fibers giving the mass a decided schistose structure, the mica is not well crystallized in distinct scales. The quartz is generally in excess of the mica and the mass is locally full of quartz veins. Another type of rock in this belt occurs in North Yallo Bally and locally along the lower portion of the southwestern slope of South Fork Mountain. The rock is greenish, generally more or less schistose, and composed chiefly of quartz and epidote. The occasional presence of blue hornblende in this rock suggests that it may be the result of contact metamorphism, but the field relations as far as known are not decisive.

The rocks bordering the schists of the South Fork Mountain upon both flanks are strongly contrasted with each other as well as with the schists. Upon the northeast are Devonian limestones, sandstones and shales cut by many igneous masses and decidedly metamorphosed. Upon the southwest between Mad River and the coast are conglomerates, sandstones and shales, at least in part of Cretaceous age. They are but little metamorphosed and are associated with comparatively few igneous rocks. The change from the schist to these rocks near Mad River is striking and indicates a profound break which may be most conveniently considered as the southwestern limit of the Klamath Mountains.

The general dip of the less altered sedimentary formations bordering the schists of South Fork Mountain belt upon both

* Included in the Abrams and Salmon formations of Hershey. Am. Geol., June, 1901, and manuscript map.

sides is to the northeastward and the fissile structure of the schists, although greatly crumpled, is for the most part in the same direction, suggesting that the quartz epidote schist upon the southwest side may be older than the sericite schist.

Northeastern belt of schists.—The northeastern belt of schists was seen only in the drainage of Salmon River and along Browns Creek near Douglass City on Trinity River. Although in general character the sericite schist of Brown Creek is like that of South Fork Mountain, its associations are quite different. On the west side it is limited by the belt of sediments containing the Hall City limestone, which is Carboniferous, and upon the east occurs a mass of schistose hornblende rocks apparently of igneous origin.

The South Fork Mountain belt of sericite schist is in general quite regular in outline and free from igneous masses, but the northeastern belt in Bully Choop and Salmon Mountains is much broken by a great variety of igneous intrusions.

Devonian.

Southwestern Devonian belt.—In the southwestern belt there is a line of Devonian limestone lentils* which may be traced with many interruptions for over 100 miles parallel with the South Fork of Trinity River from its source to near Hoopa Valley, and throughout the whole distance the limestone rarely gets over a mile or two away from the contact with the schist of South Fork Mountain. It is probable that the same limestone occurs on the western slope of the Sacramento Valley at the Basin about 30 miles west of Red Bluff, where traces of crinoids, corals and other doubtful forms were found (1887) in one of a group of limestone ledges.

The first locality in this belt visited last summer was White Rock near the head of the South Fork of Trinity River, a few miles northwest of North Yallo Bally Mountain. The limestone is intimately associated with and broken by igneous rocks, some of which are vesicular as of surface flows. The caverned mass of limestone, which is scarcely an eighth of a mile in length, has tumbled down the slope, forming prominent cliffs and talus for nearly 1,000 feet. It is rather crystalline and the few fossils obtained were numbered 704.

Northwest from White Rock, within three-fourths of a mile, several small lenses of limestone crop out, and from one of these, only three feet in greatest extent, a number of shells and coiled forms were obtained and numbered 705. Concerning these fossils, Mr. Charles Schuchert of the U. S. National Museum at Washington, D. C., reports as follows:

* Judging from the earlier collections, this belt of limestone was doubtfully referred to the Jura-trias, U. S. Geol. Survey Bull. 196, p. 64.

"Loc. 705 has *Posidonomya* (very common) and two species of Ammonoids of the family *Prolecanitidæ*. Locality 704 (White Rock) has the same species of *Posidonomya* as that of 705 and with it is associated *Stromatopora* and other fossils too obscure to determine. The preservation of the ammonoids is such that one cannot make a certain determination of them, and yet their association with *Stromatopora* and *Posidonomya* seems to warrant the conclusion that the horizon of the limestone of 704 and 705 is in the Upper Devonian."

Associated with the small fossiliferous limestone, three-quarters of a mile west of White Rock, is a small mass of red chert with the usual round clear spots of murky silica, but no definite radiolarian structure could be found. Shales and sandstones are uncommon and much disturbed, but like the limestones generally strike northwest and dip northeast. These limestone lentils with others in the same strike occur within a few hundred feet of the mica schist of South Fork Mountain, and their outcrops were traced at intervals along this part of the South Fork of Trinity for over 10 miles.

Twenty miles further northwest we again examine the South Fork limestone belt beginning near the mouth of Rattlesnake Creek.

From Rattlesnake Creek near its mouth northwestward for several miles, there is a series of limestone lenses nearly in line and increasing in size northward to a point where it forms cliffs 100 feet in height. The outcrop has a length of about a quarter of a mile and a thickness of 50 feet. On the steep slope beneath the limestone cliff is a mass of basic igneous rock, part of which like a lava flow is full of cavities while other parts are volcanic conglomerate or tuff. In the conglomerate occur large and small fragments of slightly fossiliferous limestone (709a) like that of the main mass (709 and 710), as though the fragments were broken off during an eruption. The limestone mass itself is cut by an irregular body of the same igneous rock. The general strike of the limestone is parallel to the South Fork of Trinity, above which it rises 1,500 feet at a distance of over a mile. The rocks lying between the limestone and schist at this point are largely altered by igneous rocks and locally converted into hornfels.

The rocks exposed about the limestone ledges are almost wholly igneous of basic types related to gabbro and serpentine.

The same belt of limestone becomes prominent again about 20 miles further northwest in township 2 N., R. 7 E., on the summit of the divide west of Indian Creek. As at White Rock the sparsely fossiliferous limestone (711) is much broken up, covering acres of the gentler slope, and associated with it is

the same vesicular basaltic rock seen at so many other places. Upon the western side occur slaty siliceous rocks with spots suggesting organisms, but to the eastward on the Indian Creek slope igneous rocks abound.

Before following this line of limestones further northwest, it seems best to note several small masses which occur about eight miles northeast of the South Fork line but in approximately parallel position. One is on the divide between Prospect and Hay Fork creeks where fossils 703 and 706 were collected, and the other one and one-half miles southwest of Peanut where traces of fossils (707) were obtained.

Concerning the fossils from the last two localities as well as those near the mouth of Rattlesnake (709, 709a, 710) and 20 miles further northwestward 711, Mr. Schuchert reports as follows:

"Localities 703, 707, 709, 709a, 710 and 711 have in common one fauna in which the prevalent fossil is a coral of the genus *Chætetes*. I have had sections made of it and these I have shown to Mr. Ulrich, who said that this type of *Chætetes* is that of the Devonian and not of the Carboniferous. Associated with the *Chætetes* is a compound *Cyathophyllum*-like coral and a *Cladopora*, too much metamorphosed to be determined. At locality 709 there are two or three species of Stromatoporoids."

"While the limestone of these localities is greatly metamorphosed, yet the preservation allows the making out of the genera *Chætetes, Cladopora* and *Stromatopora*. This association is clearly indicative of the Devonian, and as the other California Devonian localities, excepting 704 and 705 already noted, are of middle Devonian time, it may be best to refer the above mentioned Klamath Mountain places to the same division."

"Loc. 706 is apparently of the same limestone belt as that of 709, but the fossils are too obscure to determine this with certainty."

Continuing northwestward from Rattlesnake Creek, the limestone crosses Butter Creek near its mouth and the South Fork of Trinity a few miles above Hyampom, and although it may occur at many points within the next 40 miles it was seen only at Three Forks Creek on the wagon road from Eureka to Hoopa Valley, where it yielded a few imperfect fossils among which Mr. Schuchert recognizes "A species of *Chætetes* and a *Cyathophyllum*-like coral common to nearly all the Devonian limestone outcrops along the South Fork."

Northeastern Devonian belt.—The northeastern belt of Devonian limestones and shales lies chiefly in the Sacramento drainage extending northward into the Klamath and Rogue River region. The southern part lying within the Redding Quadrangle, and as far north as Gazelle, has already received

much attention.* The principal limestone bodies rich in fossils occur near Klamath and on Hazel Creek. Smaller masses outcrop near Horsetown and at a number of points six, eight and eleven miles northeast of Redding, where they lie close to the Carboniferous in line with a larger mass two miles northwest of Baird.

One of the best sections of these rocks, but not including the whole Devonian series, may be obtained on Backbone Creek three and one-half miles north of Kennett, where nearly 900 feet of sediments are quite fully exposed.

1. Conglomerate	30 feet.	Many quartz pebbles and numerous holes from dissolved limestone fragments, some of which contain fossils like those of the limestones below. Unconformable on 2. Possibly Carboniferous.
2. Shales	140 "	Mostly dark with some thin sandy beds.
3. Limestone	100 "	Rather massive, and light colored, little chert but full of corals, etc. (6242).
4. Shales	300 "	Thin bedded sandstones and shales which are cherty and gray below. Near middle part is limestone lens 10 to 15 feet thick.
5. Limestone	250 "	Thin bedded and crowded with massive, branching and cup corals (6244). Cherty nodules and bands in bluish limestone becoming whitish and without chert below.
6. Siliceous shales	75 "	10 feet of banded chert at top with sandy shales, black shale and fine shaly sandstone, very thin bedded, resting on the igneous rocks below.

A large number of fossils were collected from the Devonian of the Redding Quadrangle, and these may in large part be referred to the section given although but few of the fossils were actually collected at the point where the section was measured. After enumerating a number of the species found at various localities, Mr. Schuchert concludes as follows:

* H. W. Fairbanks, Cal. State Mining Bureau, 11th Ann. Rept., 1893, pp. 47–49. Also Am. Geol., xiv, 30, 1894. J. S. Diller and Chas. Schuchert, this Journal (3), xlvii, 416, 1894. J. P. Smith, Jour. Geol., ii, 391, 1894. F. M. Anderson, Cal. State Mining Bureau Bull. No. 23, 1902, pp. 39–102.

"*Summary of the foregoing lists of fossils.*"

"The section of locality 6,242 given me by Mr. Diller, the thickness of which he estimates to be about 900 feet, has one general fauna indicative of the Middle Devonian. The general age has been known for some years, but the collections of 1902 have given us a definite section and also species that are known to occur in other American localities. This is especially true of the fossils of the Lower shale zone, which repeats the fauna of the Eureka and White Pine Districts of Nevada and the Middle Devonian of Iowa. The species that are common to at least two of these regions are *Schizaphoria striatula, Stropheodonta canace, Gypidula lotis, Pugnax altus, Atrypa missouriensis* and *Crytina missouriensis?*"

"Taking these species in connection with the corals of the limestones, as *Heliolites porosa, Endophyllum* or *Spongophyllum* and *Phillipsastraea,* one sees plainly that the California Middle Devonian belongs to the 'Euro-Asiatic province'. This province extends east in North America as far as Central Missouri, Eastern Iowa, Milwaukee, Wisconsin, and Petosky, Michigan. East of these places occur the Middle Devonian faunas of the "North American type."

Continuing northward from the Kennett region the Devonian limestones and shales are well exposed, rich in fossils on Hazel Creek and Soda Creek, as well as near Gazelle, 20 miles northwest of Mount Shasta. Notes concerning all of these localities have been published, but there remains to call attention to a limestone three miles northeast of Kerby, in Oregon, which has furnished a few indistinct fossils. "A species of *Chætetes* and a *Cyathophyllum*-like coral," common to the Devonian limestone near South Fork have been recognized by Mr. Schuchert.

Carboniferous.

Southwestern Carboniferous belt.—This belt of limestone lenses and associated shales and sandstones lies some distance southwest of the schists of Bully Choop and Salmon Mountains and is bounded west by the Devonian belt of the South Fork of Trinity River. Small masses of limestones in this belt were first seen on the stage roads below Harrison gulch in Shasta County and found to extend northwest across the divide to the Hall City mines and beyond by the base of Chanchelulla to Hay Fork and Bridge Creek, where one of the lenses forms a remarkable natural bridge. From Hay Fork Valley the limestones extend up Baker and Big Creeks, and were not seen again until New River was reached near Patterson's Ranch.*

* U. S. Geol. Survey Bull. 196, p. 64.

The best section in this belt was obtained five miles north of Wildwood and one mile east of Hay Fork, where the limestone is yellowish gray and crystalline with inconspicuous oolitic structure. The mass is less than a quarter of a mile in length and has a thickness of about 200 feet. Upon the southwest it is underlain by nearly 100 feet of reddish siliceous beds succeeded below by a great mass of basaltic rock which forms the bluffs along Hay Fork Creek. Upon the northeastern side the limestone is overlain by 100 feet of yellowish and reddish siliceous shales limited by the same sort of igneous rocks as that below. In the neighborhood of Harrison gulch there is much black shale, but its relation to the limestone was not determined. Associated with the Carboniferous, as also with the Devonian, there is an abundance of igneous rocks, especially of a basic type, and they occupy much larger areas than the sedimentary rocks.

Fossils were found at five localities in this belt of Carboniferous, and with many others from the northeastern belt were referred to Dr. George H. Girty, who reports the following forms from the Hall City locality (702):

Alga.
Amblysiphonella, two species.
Sponges, miscellaneous.
Zaphrentoid coral.
Fistulipora sp.
Rhombopora sp.
Stenopora? sp.
Miscellaneous Bryozoa.
Martinia?, two species.
Spirifer or Spiriferina.
Spirifer? sp., resembling Spirifer sulcifer Shumard.
Rhynchonella, resembling Uncinulus Theobaldi Waagen.
Camarophoria? sp., near S. superstes Verneuil.
Stacheoceras n. sp.
Gasteropod undet.

From the limestone five miles north of Wildwood and one mile east of Hay Fork Creek (701) Dr. Girty reports:

Alga.
Archæocidaris sp.
Crinoid stem.
Orthis sp.
Fusulina? sp.
Lithostrotion? sp.
Archæocidaris sp.
Crinoid stem.
Productus, cora type.
Martinia? sp.
Camarophoria? sp.
Enteletes? sp.
Orthis sp.
Squamularia Guadalupensis Shumard?
Seminula? sp.
Spirifer sp.

"One of the most common and at the same time peculiar fossils collected at this group of localities is a small pagoda-like body whose exact affinities are very puzzling, but which I believe will prove to belong to the calcareous algae. Small concretionary forms, which appear to be inorganic, are also common. The fauna for the most part, however, is scanty

and obscure, not only because of the matrix, which is often considerably metamorphosed, but owing to the zoological relations of the forms present. Perhaps the most diagnostic fossil is an ammonite which was sent to Prof. J. P. Smith, who places it in the genus Stacheoceras, remarking:

'While Poponoceras in the broader sense ranges from Coal-measures to Middle Trias, the group of Stacheoceras has never been found outside of the Permian. It is therefore probable that the beds from which the Californian species was taken belong to the Permian. The species appears to be new, but resembles some form described by Gemmellaro from the Permian of Sicily.'

"Fusulina also has been somewhat questionably identified. It is impossible to doubt that this fauna is Carboniferous, and many indications point to its being late in the epoch. It is a remarkable fact that this fauna is related to those whose typical area is about Baird in only the most distant degree. It is quite unlike the faunas of either the Baird shales, the McCloud limestone, or the McCloud shale, so far as they are known; and it seems likely that its stratigraphic position must be above the McCloud shale. The apparent Permian age of this fauna, and the occurrence in it of a shell probably identical with *Squamularia Guadalupensis* Shumard and another resembling *Spirifer sulcifer* Shumard, suggest that it may belong to the fauna for which I recently proposed the regional name Guadalupian. In a general way the abundance of calci-sponges at Station 702 is evidence in the same direction, although it is undeniable that the common types constitute a small proportion of either fauna."

In the central part of the Klamath Mountains drained by the Salmon River there are a number of limestone ledges intimately associated with igneous rocks, but, as far as I am aware, fossils have not yet been found in them. To the eastward, in the drainage of Scott River about Scott Valley, a number of limestones occur. One near Oro Fino in Scott Valley and another near Parkers, on the mountain road from Gazelle to Callahans, containing pentagonal crinoid stems were formerly referred to the Juratrias, but as these fossils have been found in both the Carboniferous and Devonian limestones further south in the Klamath Mountains, the limestones in question may well be Paleozoic. This is rendered more probable by the occurrence of well-marked Devonian in the mountains west of Gazelle.

Northeastern Carboniferous belt.—The northeastern Carboniferous belt forms but a small part of the Klamath Mountains, being limited to the eastern projection beyond the Sacramento River in Shasta County. Although known for many years,

information concerning this belt has been greatly extended within the last decade by Fairbanks, Smith and Anderson in the publications already referred to.

The limestone where fully developed is the largest known in nothern California. It has a thickness of fully 2,000 feet and can be traced almost continuously along the McCloud River for nearly 50 miles. Before reaching the lavas of Mt. Shasta, however, it extends to the eastward, cropping out on the summit of Grizzly Peak, on the divide between the McCloud and Kosk Creek.

Beneath the McCloud limestone is a thick series of shales and sandstones with some conglomerates and occasional lenses of calcareous material. The sediments are often largely of volcanic matter, and include the "Baird shales" from which J. P. Smith* has described a large fauna. Above the McCloud limestone is a similar series in the McCloud shales of Smith but not so thick as the Baird formation, and grading upward into an extensive series of volcanic rocks.

Concerning the collections from the northeastern Carboniferous belt, Dr. Girty reports:

"A large part of the Carboniferous collections made in 1901 and 1902 were derived from horizons stratigraphically referable to the Baird shale, the McCloud limestone, and the McCloud shale, and from localities in the typical areas. The faunas of these beds have been listed long since by J. P. Smith,† and the more recent collections add little of material importance to the lists made at that time. It may be remarked, however, that recent collections made in the Carboniferous of Alaska are so suggestive of the fauna of the McCloud shale, by way of containing the same or similar species, as to indicate the extension of this fauna, and, possibly, of the earlier Carboniferous faunas of the California province, to this region."

The Bragdon formation, named by Hershey,‡ is here referred provisionally to the base of the Carboniferous sediments and require separate consideration. It is a mass of shales with thin-bedded sandstones and lenses of remarkable conglomerate, which is characterized chiefly by the silicious and calcareous pebbles it contains. The pebbles are generally less than an inch in diameter but, very rarely, are 12 inches through, and the majority of them are of cherty quartz. Those of limestone are occasionally fossiliferous and on the surface dissolve away, leaving holes in the conglomerate.

The distribution of the Bragdon formation is peculiar. Its eastern border lies east of the Sacramento, from Morleys to

* Jour. Geol., ii, pp. 593–602.
† Jour. Geol., ii, pp. 588–612, 1894.
‡ Am. Geol., xxvii, 236.

beyond Delta, and adjoins the Baird formation. To the westward it is limited in part by the Devonian near Kennett, but chiefly by the igneous rocks of Trinity and Salmon Mountains. To reach the latter it overlaps the Devonian limestones, shales and sandstones and covers them near the Sacramento between Backbone and Hazel Creek. Judging from its areal distribution and stratigraphic relations, it appears to belong to the lower portion of the Carboniferous section of that region.

Fossils were collected from the limestone pebbles at many points on both sides of the Sacramento. Although in a majority of cases the fossils are clearly in transported fragments derived from an older limestone in place, in other cases the same fossils are directly enclosed by the paste of the conglomerate without distinct evidence of such derivation. Concerning the fossils from the pebbles, Mr. Schuchert regards them as of Devonian age identical with those in the limestone of the Kennett region. He says "As to the age of the conglomerate I can only say that it is younger than the Middle Devonian."

The relation of the Bragdon formation upon the eastward to the Baird, appears to be that of conformable stratification, and Baird fossils have been found close to but not within the area assigned to the Bragdon formation. Conglomerates in the Baird formation contain the same fossils in pebbles and paste, especially when there is considerable igneous material. Similar tuffaceous conglomerates with fossiliferous limestone fragments occur at several horizons higher in the section.

The only fossils yet found in the Bragdon formation which certainly belong to its period of deposition, are some plant remains enclosed in light colored sandy shales a few miles west and northwest of Slatonis.

These specimens were all referred to Professor William M. Fontaine, who examined the material with great care, and fully recognizing the macerated condition of the specimens and their distortion after burial, remarked "that it is impossible to determine positively even their generic character." However, "All the imprints which show any recognizable features are strongly suggestive of Brachyphyllum." "Brachyphyllum is most developed in the Jurassic and lowest Cretaceous. If we may regard this plant as belonging to that genus, then, so far as its evidence goes, the strata are Jurassic or lowest Cretaceous. But as the generic place of the fossil can not be determined decidedly, and the amount of material is so small, the age can not be certainly fixed. A Jurassic age is indicated." With the conclusions of Professor Fontaine, Professor Lester F. Ward fully concurs.

Considering the importance of the imperfect fossils and

their determination by Professors Fontaine and Ward as doubtful, it seemed desirable to have them examined by other paleobotanists who worked in different fields. Accordingly Mr. David White, who is especially familiar with plants of the Carboniferous period, and Mr. F. H. Knowlton, whose studies are chiefly of upper Cretaceous and Tertiary forms, were asked to examine them.

Mr. White reports: "After carefully examining the Slatonis collections I can say but little except that the material is so fragmentary, so badly macerated, and so altered as not to justify any conclusions regarding its age." After fully describing all the plant fragments found in the specimens and weighing probabilities, Mr. White remarks:

"In brief, with the exceptions of the supposed cone fragments, I find nothing in the collection which is not entirely in accordance with an Upper Paleozoic date for the plants, while there is slight evidence, entitled to but very little weight, that the plants are of Upper Devonian or Lower Carboniferous age. The other plant material in hand is, however, of little weight to the contrary if the supposed cones are genuine, for, in the latter case, I believe the beds should be regarded as post-Paleozoic. Concerning the genineness of the cones I personally am somewhat in doubt."

Mr. Knowlton says: "I have given them a very careful study not only to-day but before this. In size and shape they do at first glance strongly suggest cones, but the more carefully they are looked at the less can I satisfy myself that they are cones. Mr. White has well described their appearance and it is not necessary for me to again go over the ground. There are a number of 'remains' on the rocks that have the same size and outline as the supposed cones, but a glance is sufficient to show that they are not such, and hence in the two or three examples that look most like cones I am inclined to regard them as also accidental. In any case I think it is perfectly safe to say that the material is too poorly preserved and fragmentary to base any important geological differentiation on, certainly as deciding whether the beds are Paleozoic or Mesozoic."

The geological age of the Bragdon formation is yet a matter of doubt. It is certainly younger than the Middle Devonian and probably belongs to the base of the Carboniferous section in that region, although it is absent in some places where it ought to appear. Largely on lithological evidence it has been referred by Hershey* to the Jurassic, and by Anderson† to the Triassic, but the fossils found thus far do not

* Am. Geol., xxvii, p. 236.

† Calif. State Mining Bureau, Copper Resources of Calif.—Geological Map of western part of Shasta County.

strongly support either view. The characteristic fossils common in the Pit formation (Triassic) of the same region, as well as the plant remains so well known in the Jurassic of Mariposa, California, and several localities in Oregon, were carefully sought for but not found in the Bragdon formation.

Triassic.

The part played by Triassic sediments in the structure of the Klamath Mountains is small, for they are known to occur with certainty only in Shasta County along Squaw Creek, between the McCloud River and the Great Bend of Pit River. The rocks of this age embrace the Pit formation, composed largely of shales associated with a smaller proportion of tuffs and conglomerates, and the Hosselkuss limestone 200 feet in thickness overlain by shales locally rich in *Monotis subcircularis*. The Triassic formations appear on Cedar Creek. Coming out from under the later lavas of the Lassen Peak region, they strike nearly southwest to the vicinity of Furnaceville, where they turn northerly, crossing Pit River, and then northeasterly about the head of Squaw Creek, where they are limited by the Carboniferous of Grizzly Peak, and disappear under the great lava field of northeastern California. Undoubtedly the Triassic formations once extended much further westward into the Klamath Mountains than now and have been removed by the great erosion of the Cretaceous and Tertiary periods.

Jurassic.

Jurassic strata like those of the Trias enter into the Klamath Mountains to a small extent only, and occur along the western arm of the Great Bend of Pit River, rich in fossils like those of the Taylorville region.* Shales and sandstones are common and occasional lenses of fossiliferous limestone occur in them. Conglomerates are not rare and usually contain much igneous material. Near the base they include interesting limestone fragments and nodules which are fossiliferous.

Cretaceous.

Cretaceous strata almost encircle the Klamath Mountains and a few isolated patches cling to their flanks, especially about the northern and southern ends, throwing an important light upon their history. Some of the outliers were noted in the preliminary map† and others have been discovered and published since.‡

* Geol. Soc. of Am., iii, pp. 369–412.

† U. S. Geol. Survey, Fourteenth Annual Report, pl. xlv.

‡ F. M. Anderson in the Jour. of Geol., x, pp. 144–159; also Proceedings of the California Academy of Sciences, Third Series, Geology, vol. ii, No. 1, 1902, and O. H. Hershey, this Journal, xlv, pp. 33–37.

It should be stated that in the supposed Cretaceous area on Post Creek near its junction with Rattlesnake some imperfect plant remnants were found last summer, concerning which Mr. Knowlton reports: "The best preserved specimen is a portion of a leaf apparently identical with that Fontaine has identified as *Angiopteridium strictinerve latifolium* in a forthcoming paper with Professor Ward on the flora of the Shasta group. This material would seem to be Cretaceous and to be similar in age to the Shasta."

The outliers at the southern end, as pointed out by Hershey, are aligned approximately northeast and southwest parallel to the Bully Choop Divide and the Cretaceous at its eastern base. The strike of the beds in the largest isolated area of Cretaceous, that of the Redding Creek basin, ranges generally between N. 55° to 71° E. and dips to the southeastward, indicating a line of deformation nearly perpendicular to that which determined the surface distribution of the rocks older than the Triassic.

Towards the northern end of the Klamath Mountains on the head of the Middle Fork of Smith River, and on the Illinois River near Waldo and Kerby, a mass of fossiliferous sandstones, conglomerates and shales occur resting with marked unconformity upon older rocks. Among the fossils, a number of which were new species, *Pecten operculiformis* and several other forms were determined. Concerning the collection as a whole Dr. Stanton reports: "There is a lack of well known characteristic species but the collection is probably from the Horsetown." The basal conglomerate near Waldo is composed almost wholly of sandstone fragments and not of peridotite or serpentine which are so abundant in that neighborhood, suggesting that as in other localities further to the northwest the peridotite was erupted after the Horsetown beds were deposited.

The greatest extent of this area is approximately northeast and southwest along the road from Waldo much of the way to Grant's Pass, and continuing in the same direction beyond Rogue River less than a score of miles over other rocks, brings one to the Graves Creek locality of Cretaceous sandstone and conglomerate so rich in fossils. The distribution of these two areas suggests that they occupy depressions in the same trough, which is in general parallel to a closely related line of outcropping Cretaceous extending from the vicinity of Riddles southwest across Rogue River to the coast near the mouth of Pistol River.

The general distribution of the Knoxville, Horsetown and Chico beds in the Klamath Mountain region is such as to confirm the conclusion long since drawn, that the Cretaceous

period was one of subsidence and the sea gradually transgressed until the Klamath Mountain region was almost if not completely covered by the sea. The remnants of the once extensive Cretaceous deposits on the flanks of the Klamath Mountains contain only open sea forms, and all were once continuous. Their present distribution is due to post-Cretaceous folding along axes running approximately northeast and southwest, or nearly perpendicular to the lines of older deformation which determine the distribution of the Paleozoic rocks in the Klamath Mountains. Anderson in his Physiography of the Klamath Mountains refers to two systems of folds and regards the northwest-southeast folds as the younger. It is possible, however, that a series of movements occurred along both systems at various times throughout their geologic history.

Eocene.

Eocene strata of marine origin touch the northern end of the Klamath Mountains on Rogue River at the mouth of the Illinois. They are chiefly sandstones with shales and conglomerates well characterized by various fossils and locally containing small masses of coal.

During the Eocene the Klamath Mountain region was a land area and only fresh water deposits could reasonably be expected within its borders and along its eastern base. In the vicinity of Ashland, Ore., sandstones and conglomerates occur containing fossil leaves which were once considered Miocene, but now that the beds of the John Day region have been thoroughly studied, the beds near Ashland are regarded by Mr. Knowlton as Eocene.* Some fossil leaves recently found in the Hay Fork beds according to Professor Knowlton appear to be Eocene. They will be noticed, however, in connection with associated strata of Miocene age.

Miocene.

The preliminary general geological map of the Klamath Mountain region† shows five areas of Miocene deposits, the largest of which is about Weaverville upon the southern border of the Klamath Mountains. Some notes were published concerning these deposits in the Fourteenth Annual, and later in Bulletin 196.‡

* U. S. Geol. Survey, Bulletin 204, p. 111, and letter dated Feb. 17, 1903.

† Plate xlv, Fourteenth Annual Report, U. S. Geological Survey.

‡ These deposits and others closely related have been discussed also by Mr. F. M. Anderson (The Physiographic Features of the Klamath Mountains, Jour. Geol., x, 144), and by O. H. Hershey (Neocene Deposits of the Klamath Region, California, Jour. Geol., x, 377).

In the Hay Fork region observations were extended last summer and a number of fossils collected which throw a stronger light upon the age of the deposits, and will help ultimately, when all the evidence is disclosed, to form a more complete picture of the conditions of deposition.

Hay Fork Valley has a length east and west of about 11 miles and a width of less than two miles. Looked at from the west, one is impressed with the contrasting slopes bounding the valley. The long gentle slope on the north side and the steep abrupt one on the south side suggest that the valley is largely the result of displacement. The fine shales and sandstones which fill the valley are well exposed on Hay Fork Creek below the mouth of Salt Creek, where they contain impure coaly layers and are locally full of shells of a fresh water gasteropod, and also of fruit and leaves. The light-colored beds have a thickness of several hundred feet and dip in various directions from 30 to 50 degrees, with strike in some places northeast and in others northwest.

The shells are very abundant throughout a thickness of nearly 100 feet and although not found with leaves in the same stratum were found within a few feet of leaves numbered 6170. The shells were referred to Dr. Dall, who reports as follows:

"The fossils consist of a single species of *Vivipara* very much crushed, and therefore hardly identifiable specifically. In a general way it is not unlike an undetermined species of '*Campelonia*' described and figured by Meek in the 40th Parallel Survey from Bear River, Utah, and referred with the other species from that horizon to the Cretaceous. There is no *Vivipara* known at present from California, either recent or fossil. I should say the species cannot be newer than the Pliocene and may be as old as the Cretaceous."

The fossil leaves collected from the Hay Fork beds were referred to Professor F. H. Knowlton, who reports as follows:

"No. 6164. Hay Fork Creek, 100 yards below the mouth of Salt Creek, three-quarters of a mile west of the town of Hay Fork.

"No. 6169. Tule Creek near its mouth into Hay Fork Creek, one and one-half mile west of town of Hay Fork.

This material is similar, being a fine-grained, soft and highly carbonaceous clay. It is filled with fruits of *Trapa*, of the type of the living *Trapa natans*, nothing else being present. The fruits are mostly broken, but a sufficient number are so preserved as to leave no doubt as to their nature. When the 'horns' are broken away from the body of the fruit they very much resemble small shark's teeth, and were so identified last year.* Trapa

* U. S. Geol. Survey, Bull. 196, p. 43. Report by Mr. F. A. Lucas.

is fresh water aquatic, growing in shallow water, its roots anchored in the mud and its numerous leaves forming a rosette on the surface of the water. It is difficult to understand how so many of the fruits could have been preserved without a trace of a leaf.

I have described two species of Trapa from the lake beds of the Payette formation of Boise County, Idaho, one of which (*T. occidentalis*), 18th Ann. Rept. U. S. G. S., Pt. III, pl. cii, fig. 7b, is of the same type apparently as certain of the fruits from Trinity County, Cal. They are probably not identical, although so far as I can see the difference is mainly one of size.

"No. 6170. Hay Fork Creek, opposite Van Metres, two and one-quarter miles west of the town of Hay Fork.

This material is a soft, bluish or greenish clay and has the fossil plants well preserved. I find the following species :

Sequoia angustifolia Lesq.
Salix angusta? Al. Br.
Salix Californica Lesq.
Quercus convexa Lesq.
Quercus elænoides Lesq.
Ficus ungeri? Lesq.
Aralia whitneyi Lesq.

These are all more or less well known Auriferous Gravels species except *Ficus ungeri*, which is doubtfully identified here. It is normally a Green River species, and it will probably be found that the Hay Fork leaves are similar to but not quite identical with it. The identification of *Salix angusta* is also somewhat doubtful. That the flora we are here considering is similar in age to the Auriferous Gravels is clear, but in the light of more recent work it is perhaps desirable to attempt to fix, if possible, the part of the Auriferous Gravels they most resemble. Of the four species clearly identified, typically Auriferous Gravels (*Salix Californica, Quercus convexa, Quercus elænoides* and *Aralia whitneyi*), three are found at Table Mountain and one at Chalk Bluffs.

Turner is of the opinion that the Table Mountain locality is of later age than the Auriferous Gravels proper, while Lindgren regards it as pretty definitely settled that Chalk Bluffs is similar in age to Iowa Hill and Independence Hill, that is of the age of the bench gravels or lowest rhyolitic tuffs. He regards them as upper Miocene and I see no reason to question this.

From this meagre evidence it appears that the Trinity County leaves under consideration are most like those from Table Mountain, but this whole subject must await a thorough revision of the material and available data before any thoroughly satisfactory or reliable conclusions can be reached. I have a large amount of material from various localities and as soon as possible it is my intention to work it up with a view to fixing the horizons and whence it came, but until that is done I can hardly venture more

than to say that the Trinity leaves are similar in age to a part of what has been called the Auriferous Gravels.

"No. 6168. Hay Fork Creek, one and three-quarter miles west of town of Hay Fork. A considerable collection of material, the matrix being a soft sandstone.

The following are represented:

Juglans Schimperi Lesq.
Populus Heerii Lesq.
Rhamnus? sp.

The first species is present in great abundance and in perfectly typical examples, while the last (*Populus Heerii*) is so closely similar to the type that it might almost have been the original from which the figure was made. I state this for the purpose of showing that there can be no question as to their identification. These two species are found at Florissant, Colorado, and should be referred to the upper Eocene.

I think the material from this locality is probably the same as that which I reported on last year, referring it with hesitation to the upper Miocene. Only two species were present in that collection and both are of general distribution throughout the Tertiary. With the present collection the matter is different; the forms recognized are clearly older, and I am forced to the conclusion that there must be two horizons represented in the Hay Fork area."

The new points concerning the Hay Fork beds brought out by this collection are: (1) The determination of the supposed shark's teeth as fruit of a fresh water plant removes the chief argument tending to show that the Hay Fork beds were formed in an estuary near sea-level. (2) The Hay Fork beds are now not only more definitely correlated to the Auriferous Gravels but with a portion of them of upper Miocene age. (3) The recognition of Eocene forms is somewhat of a surprise. In the field all the beds in Hay Fork Valley were supposed to be of the same age. The layers containing the upper Miocene forms (6170) are from the west and lowest end of the valley and without intervening Eocene beds rest directly with marked unconformity on the adjacent Paleozoic rocks.

Pliocene.

Along the northern side of Hay Fork Valley there is a mass of white tuff at least 15 feet in thickness which is closely related to a similar deposit in the Redding Creek basin of the same region. These deposits are of but little importance as to size, but as a time-marker they may become important in correlating the sediments of independent basins. Considering the size of the deposit, its distribution and the general character of the material, its source is believed to be Lassens Peak,

from whose eruptions there is a great mass of tuff in the Sacramento Valley cropping out all along its western border from Gas Point to Thomas Creek. Lassen Peak is the nearest large volcano, and its known tuffs are separated from those of the basins referred to above by about 20 miles over a low mountain. With a view to determine certainly if possible the source of the material of the tuff, two chemical analyses were made by Dr. E. T. Allen. One specimen was from Rice's quarry, six miles southeast of Paskenta, representing the tuff of the Sacramento Valley; the other specimen is from the Redding Creek basin.

Analyses of Lassen Peak Lavas and Tuffs.

	1	2	3	4	5	6	7	8
SiO	58·08	68·72	76·75	70·01	65·78	67·27	60·23	70·40
Al_2O_3	18·37	15·15	12·32	12·61	14·87	14·84	18·64	13·50
Fe_2O_3	2·92	1·16		1·47	1·27	1·01	3·81	1·31
FeO	3·38	1·76	1·36	·50	1·	·85	·88	1·61
MgO	3·35	1·28	none	·72	1·89	1·36	1·64	·37
CaO	7·05	3·30	1·18	1·06	2·41	2·30	6·04	·56
Na_2O	3·66	4·26	3·55	1·94	2·58	2·94	3·87	2·11
K_2O	1·33	2·78	3·98	5·12	2·71	2·87	1·46	2·39
H_2O-	1·09	·74	·54	2·37	2·87	1·55	·95	1·05
H_2O+	---	---	---	4·68	4 32	4·95	1·97	7·41
TiO_2	·44	·31	---	---	---	·27	·57	---
ZrO_2	---	---	---	---	---	none	·01	---
CO_2	---	---	---	---	---	none	none	
P_2O_5	·16	·09	---	·04	·08	·06	·20	·08
SO_3	---	---	---	---	---	none	none	
Cl	---	---	---	---	---	---	---	---
F	---	---	---	---	---	---	---	---
S	---	---	---	---	---	---	---	---
Cr_2O_3	none	none	---	---	---	trace	trace	---
NiO	---	---	---	---	---	---	---	---
MnO	·13	0·11	---	trace	trace	trace,	trace	trace
BaO	·03	·07	---	---	---	·15	·11	---
SrO	·02	·03	---	---	---	none	·05	---
Li_2O	trace	trace	---	---	---	---	---	---
	100·01	99·76	99·68	100·52	99·78	100·38	100·43	100·79

1. Andesite. Old rim of Lassen Peak. Analyst, W. F. Hillebrand. 1887.
2. Dacite of last eruption at northwest base of Lassen Peak. Analyst, W. F. Hillebrand. 1887.
3. Glass base from dacite of Lassen Peak. Analyst, P. W. Shimer. 1883.
4. Tuff about 40 miles southeast of Lassen Peak. Analyst, George Steiger. 1893.

5. Tuff, 6 miles northeast of Paskenta, Tehama County, Cal. Analyst, George Steiger. 1893.
6. Another portion of same mass as 5. Analyst, E. T. Allen. 1903.
7. Tuff, Redding Creek Basin, Trinity County, Cal. Analyst, E. T. Allen. 1903.
8. Tuff, Hyampom, Trinity County, Cal. Analyst, George Steiger. 1893.

A number of chemical analyses of Lassen Peak lavas, including both andesites and dacites, were made some years ago and average examples are given in 1 and 2 of the accompanying table. The dacites have a glassy base which, as shown by analysis 3 is richer in silica and potash than the lava. The tuff 40 miles southeast of Lassen Peak (4) is supposed to have resulted from a late eruption of that peak and was put in for comparison with the tuff of the Sacramento Valley (5 and 6) from the same source, and afford a basis for comparison with that west of the Sacramento Valley on Redding Creek (7) and at Hyampom (8) in the Klamath Mountains. The last two are certainly not of the same eruption, for they are widely different in age. The tuff of Hyampom, so rich in particles of clear volcanic glass, contains Miocene leaves, while that of Redding Creek and Hay Fork basins is much later, overlying the Miocene shales, and of much more recent appearance. The leaf-bearing shales of Hay Fork have been found rich in infusoria and as far as seen, although like tuff in appearance, contain no particles of glass which could be identified with certainty.

Becker* called attention to much volcanic material in Lake County, and Hershey† suggested that the prevailing winds of that region being from the south the tuff in the Neocene basins of the Klamath Mountains may have come from Lake County.

As to the age of the tuffs in Hay Fork and Redding Creek basins, from the fact that they occur between the Pleistocene gravel and Miocene shales and sandstones they may be regarded in general as being Pliocene.

Pleistocene.

The Pleistocene of the Klamath Mountains embraces numerous elevated beaches along the coast as well as glacial and fluvial deposits among the mountains, but for our present purpose these have been sufficiently treated in U. S. Geological Survey Bulletin 196, page 24, and by Hershey in the Journal of Geology, volume viii, page 42.

* U. S. Geol. Survey Monograph xiii.
† Jour. Geol., x, 391.

Resumé.

The sedimentary rocks of the Klamath Mountains, excepting those which are pre-Devonian, belong to the following groups: Devonian, Carboniferous, Triassic, Jurassic, Cretaceous, Eocene, Miocene, Pliocene, and Pleistocene.

The general conclusions concerning their distribution and structural relations may be summarized as follows:

1. The Klamath Mountains, although composed in large part of igneous rocks, are made up chiefly of pre-Devonian schists with Devonian and Carboniferous sediments, among which fossiliferous limestones occur.

2. Triassic and Jurassic sediments form but a small part of the Klamath Mountains, occurring, as far as yet definitely known, only in the southeastern projection between the McCloud River and the Great Bend of Pit River.

3. The Cretaceous strata of marine origin practically surround the Klamath Mountains and occur also in separate basins within their northern and southern portions.

4. The Eocene, Miocene, Pliocene and Pleistocene sediments near the coast are of marine origin, but inland among the Klamath Mountains some, if not all, of the basins containing marine Cretaceous beds contain also fresh water Eocene, Miocene, Pliocene, and Pleistocene sediments.

5. The older sedimentary rocks, including those of Paleozoic or greater age, forming the bulk of the Klamath Mountains, are arranged in two belts running northwest from the end of the Sacramento Valley to the coast between Red Wood Creek in California and the mouth of Rogue River in Oregon.

6. The dividing line between the belts is occupied largely by igneous rocks. It lies near the southwestern base of the Bully Choop and Salmon Mountains.

7. Both belts embrace pre-Devonian, Devonian and Carboniferous sediments. The oldest rocks of each belt are upon the southwest side and decrease in age to the northeast. The prevailing dip of the strata throughout the greater part of the Klamath Mountains and the northern end of the Coast range is in the same direction.

8. This repetition of beds in the same order in the direction of the prevailing dip suggests faulting and that a great fault runs northwest and southeast near the southwest base of Bully Choop and Salmon Mountains.

9. West of the ancient schists of the South Fork Mountain, bordering the coast, lies the North Coast Range of California, composed of shales, sandstones and conglomerates which are at least in part Cretaceous and perhaps wholly of Mesozoic age.

10. Between these unaltered sediments and the pre-Devonian schists toward which they dip, there is a great break along the southwest line of South Fork Mountain marking the line between the Klamath Mountains and the Coast Range proper.

U. S. Geological Survey, Washington, D. C.

Art. XXXVI.—*Rotatory Polarization Mechanically Produced;* by Arthur W. Ewell.

Some four years ago Prof. A. W. Wright of Yale University suggested to the author that he investigate the optical effects of torsion upon transparent media, citing a reference of Verdet* to the unsuccessful attempts of F. E. Neumann and Drion to obtain rotatory polarization by twisting. The results of the author's investigation were given in a paper † published a year later in which it was demonstrated that jelly in a rubber tube, when subjected to severe twist, rotates in the opposite direction to the twist, the plane of polarization of polarized light which traverses the jelly parallel to the axis of twist, and that this rotation is a higher power of the twist than the first. In a paper‡ published a year later it was shown that this rotatory polarization was quite uniform over the cross section of a jelly tube; that it was present in an annular jelly tube formed by pouring the jelly into the space between two rubber tubes both of which were cemented to glass caps; that a glass rod twisted when heated to softness showed no rotatory polarization when allowed to cool; and, finally, that glycerine, stirred or twisted in rubber tubes, even at zero degrees showed no rotatory polarization.

The present paper describes experiments performed during the past two years, in seeking definite quantitative relations between the rotation of the plane of polarization and the twist and twisting moment and what conditions besides the twist influence the rotation. A great number of experiments were make with several forms of apparatus which afterwards proved to be merely preliminary. Only the final form of apparatus and the experiments performed with it will be described.

Material Used.

Jelly.—The great majority of the experiments were made with jelly, which is by far the best material which the author has discovered, since it may be made very transparent, possesses in a marked degree all the features of an elastic solid and allows great distortion without serious injury to its optical or mechanical properties.

In the experiments described in former papers the jelly was composed of choice calves foot gelatine and water. The jelly used in the experiments described in this paper contained in addition glycerine, which makes the jelly tougher and constant,

* Verdet: Optique ii, p. 389.

† This Journal (3), viii, 89, 1899; also abstract in Phys. Zeitschrift, i, No. 18.

‡ Johns Hopkins University Circulars, June, 1900.

neither drying up nor putrefying. The proportion most suitable for the majority of the experiments was 1^{g} gelatine, 5^{cc} water, 5^{cc} glycerine in warm weather, and in winter a little more glycerine and water. A greater proportion of glycerine to water makes a slimy jelly, less of the nature of a rigid, hard body. The stiffest jelly which is still sufficiently transparent consists of 1^{g} gelatine, $2\frac{1}{2}^{cc}$ water, $2\frac{1}{2}^{cc}$ glycerine. The mixture of gelatine, water and glycerine was heated at about 100° C. until the gelatine was completely dissolved, which usually required nearly an hour.

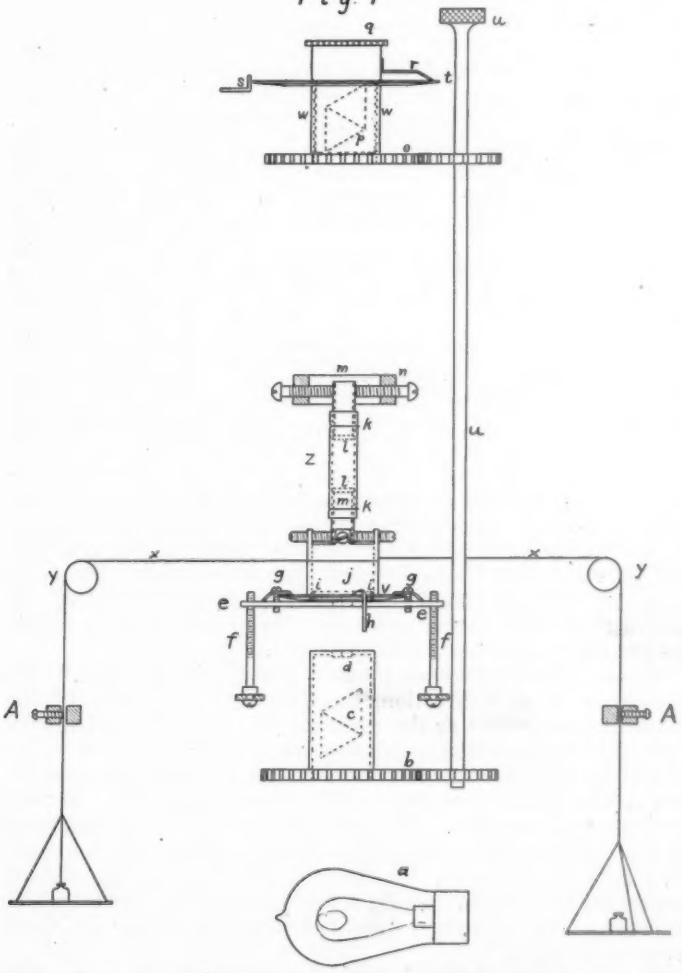
Jelly Tubes.—Most of the experiments described below were performed with jelly in rubber tubes. A different form of tube was used from that of the earlier papers. A proper length of proper sized *pure* rubber tubing was chosen and a brass tube about 3^{cm} long, the external diameter of which was slightly larger than the internal diameter of the rubber tube, was slipped into each end of the rubber tube for about 1^{cm}, a circular glass disk slightly larger than the brass tube being pushed in ahead of the brass tube. The tube was then completely filled with the melted jelly through a slit in the side. With patient manipulation air bubbles could be avoided. The glycerine jelly was so tough that it was not necessary to close the slit with wax. The rubber tube was bound upon the brass tube with wire; unless otherwise stated, the internal diameter of the rubber tube was $1{\cdot}14^{cm}$ and the external diameter of the brass tube $1{\cdot}42^{cm}$. This style of jelly tube, which will henceforth be designated as a "jelly tube," is greatly superior to the former style where square glass plates were directly cemented to the rubber tube, in that the brass tube could be grasped with far less distortion of the tube and afforded far more opportunity for adjustment than the glass plates.

Independent Jelly Cylinders.—These were constructed by pouring melted jelly into a test tube, allowing the jelly to set, then plunging the test tube into hot water which melted the jelly next the glass, allowing the cylindrical core to slip out. A suitable length was cut off with a sharp knife; short lengths of slightly smaller rubber tubing (internal diameter $1{\cdot}76^{cm}$) were slipped over the ends for about 7^{mm}. A glass disk was placed against each end inside the rubber tubing and a brass tube slightly larger than the rubber tubing (external diameter 1·90) was then pushed into the rubber tube up to the glass disk. The brass tubes were grasped in the clamps by which the twist was applied. These independent jelly cylinders were similar to what the jelly tubes would be with the central part of the rubber tube cut away. The jelly cylinder must be of exactly the popular diameter. If too large the rubber tubing is quite likely to cut it and if too small it is likely to slip in the rubber tubes.

Apparatus.

The general apparatus in its final form is illustrated in outline in fig. 1. It is a biquartz polarimeter, without lenses and

Fig. 1



with certain attachments for this particular work. The light passes from the frosted incandescent lamp, *a*, through the first Nicol, *c*, the biquartz, *d*, the jelly tube, *z*, and the second Nicol,

p, where it enters the observer's eye. The upper Nicol, *p*, is mounted in the tube, *q*, which rotates freely within the tube, *w*, attached to the gear wheel, *o*, and a graduated circle, *t*. The position of this Nicol is read with a pointer, *v*. The lower Nicol, *c*, and the biquartz, *d*, are fixed in a tube which is attached to the gear wheel, *b*. The upper gear wheel, *o*, and graduated circle, *t*, can be rotated in step with the lower gear wheel, *b*, the lower Nicol, *c*, and biquartz, *d*, by means of the rod, *u*, with its small attached gears. Thus the azimuth of polarization of the entering light, with reference to any particular radius of the jelly tube, may be varied without changing the relative position of the lower Nicol and the graduated circle of the analyzer. The circle, *t*, has a second graduation along the outer edge and the azimuth is read by means of the index, *s*. *z* represents a jelly tube of the form described above, *m* is the brass tube, *e* the glass disk and *k* the binding wire. The upper brass tube is clamped in the fixed clamp, *n* (the position of this clamp can be varied to suit different lengths of tube). The lower brass tube is fastened in the movable clamp, *j*. A graduated circle, *v*, is attached to the bottom of this clamp and the amount of twist applied to the tube is read with the index, *h*. The twist was generally produced by pulling the cords, *x*, by weights, or by hand, and then clamping the cords at A. The pulleys, *y*, had cone-bearings and turned with no appreciable friction. Their position could readily be varied. The lower clamp could be clamped in position by the clips, *g*, to the platform, *e*, which could be raised or lowered by the screws, *f*. *i* represents the cross section of a ring soldered to the platform, *e*, which fitted loosely within the lower clamp and served to keep it from being drawn too far to one side during adjustments.

Signs.—The right-handed screw notation is adopted.* If, advancing in any direction, the direction of rotation of the plane of polarization or the direction of twist of the body be related to the direction of advance as the direction of rotation of a right-handed screw is related to its advance, the rotation or twist is said to be positive while the opposite twist or rotation is called negative. The graduated circles being numbered in the usual direction, an increase in the reading means a negative rotation or twist. Twists and rotations are throughout expressed in degrees. Degrees are given to the nearest whole number. The accuracy does not warrant stating fractions, even in averages.

Double Refraction.—A double refracting body may rotate the plane of polarization of linear polarized light. Double

* Maxwell, Elec. and Mag., 3d ed., i, p. 25.

refraction and rotatory polarization may, however, be distinguished if the incident light is polarized in a number of azimuths, for simple double refraction will rotate the plane of polarization in one direction in some azimuths and in the other direction in other azimuths, for it has nothing in its nature to distinguish the two directions of rotation. In these experiments the jelly was always under some strain and, therefore, showed some double refraction. To eliminate the effect of the double refraction, which increased the proper rotation in some azimuths and decreased it in others, and also to obtain greater accuracy, readings were always made, by means of the above mentioned gearing, in eight symmetrically distributed azimuths, and *every position of the analyzer or rotation of the plane of polarization, given below, is the mean of eight such readings.*

Natural Rotation of the Jelly.—The natural rotation of the jelly (usually about 2°·7 per cm.) has been subtracted from the observed rotation in every case and the rotation stated is the difference due to the mechanical strain.

To obtain constant definite results it was necessary to determine what other conditions besides the twist influence the amount of the rotation. These conditions will now be considered in their approximate order of importance.

Conditions Influencing Amount of Rotation.

Lateral Envelope.—Aside from qualitative experiments with glass, the only successful experiments described in previous papers were with jelly in rubber tubes. It was very important to determine whether independent cylinders gave this rotation when twisted. I will give in full the last set of readings with independent jelly cylinders which were made under what previous experience had shown to be the most suitable conditions. The lower clamp was fixed by the clips, *g*, after the twist was applied. As is shown later, it would have been better to have had it hanging free, but these independent cylinders could not support this weight under twist sufficient time for reading the rotation.

Independent jelly cylinders.

July 12, '02. Initial position of the analyzer for uniform color of the two halves of the biquartz = 94.

Length (between rubber clamps) = 5·1^{cm}. Diam. = 2·1.

1′ delay after applying twist before making readings to avoid relaxation disturbances (see below).

Twist	0	120	−120	120	−120	120	−150	150
	78	88	91	92	83	74	78	85
	79	86	69	91	63	89	69	86
Readings in	82	97	79	97	83	95	76	90
the 8 azimuths	83	89	76	86	75	98	79	92
	86	89	81	88	90	89	81	87
	82	90	70	94	70	89	79	85
	79	98	71	95	82	91	73	86
	78	91	78	92	72	96	73	83
Mean position	—	—	—	—	—	—	—	—
of analyzer	81	91	76	92	78	91	76	87
Rotation due to twist....		−10	5	−11	3	−10	5	−6

Twist	−150	150	−120	120	−150	150
	82	87	94	86	77	85
	79	91	70	89	75	87
	77	91	77	93	79	90
	82	83	79	93	79	86
	83	84	95	85	77	85
	75	88	69	89	83	90
	75	86	87	85	75	87
	74	89	76	94	74	85
Mean position of analyzer	78	87	81	89	78	87
Rotation	3	−6	0	−8	3	−6

The irregularity is not surprising when one considers the strains which are unavoidable in these independent cylinders and the dependence of the rotation upon certain of these strains, as shown later. These and similar observations, some of which are cited below, show qualitatively, that *simple jelly cylinders, without any envelope, acquire when twisted rotatory polarization in the opposite direction to the twist.* It might be suggested that possibly the rotation is due to a twist of the jelly within the rubber tubing. This is scarcely possible, for the rubber is so much more rigid than the jelly that the tubing which tightly grasps the jelly hardly twists at all.

A lateral envelope greatly increases the rotation for a given twist.

Dec. 9, '01. Independent jelly cylinder, length = 8·0, diam. = 2·0.

Twist	−170	190
Rotation.....	1	−1

Soft rubber tube slipped over jelly (internal diam. = 1·76).

Twist	90	−90
Rotation.....	−6	9

Dec. 28. Independent jelly cylinder. Length = 7·0 diam. = 1·8.

Twist	210	−220
Rotation	−10	11

Rubber tube slipped over:

Twist	−240	130
Rotation	30	−13

The rotation for a given twist is increased by increasing the envelope.

July 21, '02. Jelly tube. Length (of jelly in tube) = 3·0. Lower clamp free (i. e., suspended from jelly tube and not resting on the platform *e*).

Twist	−120	120
Rotation	8	−4

Wrapped tightly with thin rubber:

Twist	−120	120
Rotation	21	−30

Thin rubber wrapping replaced by a second rubber tube slipped over first rubber tube:

Twist	120	−120
Rotation	−26	11

Longitudinal Compression and Elongation.—It was early noticed that longitudinal compression increased the rotation of the plane of polarization for a given twist, while longitudinal elongation decreased it. Measurements of this effect with the final form of apparatus are given below. The lower clamp was twisted through an angle, read with the graduated circle, *v*, and pointer, *h* (see fig. 1) and clamped to the platform *e* by the clips *g*. The compression or elongation was applied by raising or lowering this platform by the screws *f*. The length of the jelly tube was taken as the distance between two pin points, pricked into the rubber tubing outside the glass disks *l*. Decrease in length we will take as positive and increase as negative.

I. Aug. 2, '02. Jelly tube C 5. Original length = 3·33. Twist of −90.

Change in length (m.m.)	0	·5	1·2	0	−·5	−1·7	−3·9	−4·5	−2·7	0
Rotation	19	26	33	19	16	8	2	1	3	18

II. Aug. 4. Same tube. Twist = 90. (All rotations negative.)

Change in length	0	·9	2	−·8	−1·7	−2	−4·9	−·1
Rotation	18	27	43	16	11	5	4	21

III. Aug. 5. Same tube. Twist = 60. (All rotations negative.)

Change in length	0	2	3·1	·4	−·1	−1	−4	−·3
Rotation	4	9	22	4	2	1	1	2·

I. Aug. 5. Jelly tube D 1. Original length = 3·70. Twist = 120. (All rotations negative.)

Change in length	0	1·6	3	2·4	1·	−·3	−1·2	−2·8	−5	−1
Rotation	9	25	118	75	36	18	10	5	2	9

II. Aug. 6. Same tube. Twist = − 90.

Change in length	0	1·4	2·5	1·2	·5	−1·6	−3·5	−5·4	−2·4
Rotation	14	35	74	33	14	6	5	1	6

The results for tube C 5 are plotted in fig. 2, and for D 5 in fig. 3, the abscissa being change of length, x, and the ordinate, rotation, y.

Apparently, when $x = \infty$, $y = \infty$; when $x = -\infty$, $y = 0$. This suggests an exponential curve of the general form

$$y = c_1 c_2^{x} \qquad \text{or}$$
$$\log y = A + Bx$$

where c_1 and c_2 are empirical constants. In fig. 3*a* the ordinates are logarithms of the rotation and the abscissæ are changes of length as before. The closeness of these curves to straight lines indicates that the curves in figs. 2 and 3 are very approximately exponential curves.

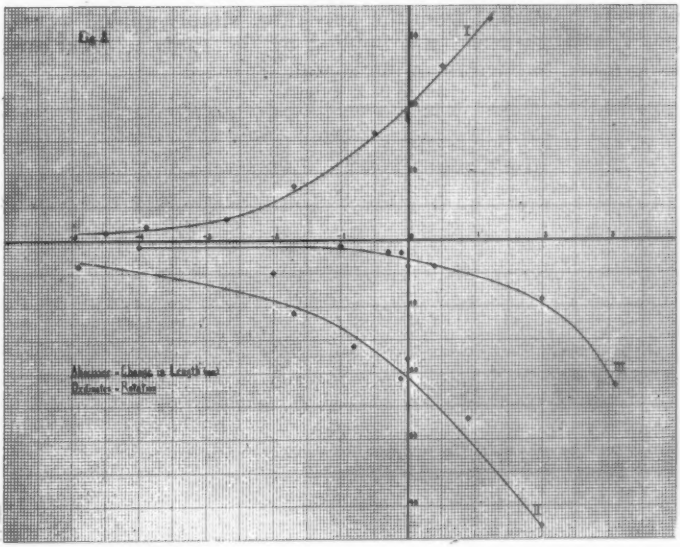
If we let x' represent the actual length, i. e., in figs. 2 and 3, x+a constant; when $x' = \infty$ $y = 0$, when $x' = 0$ $y = \infty$, which is satisfied by an equation of the form

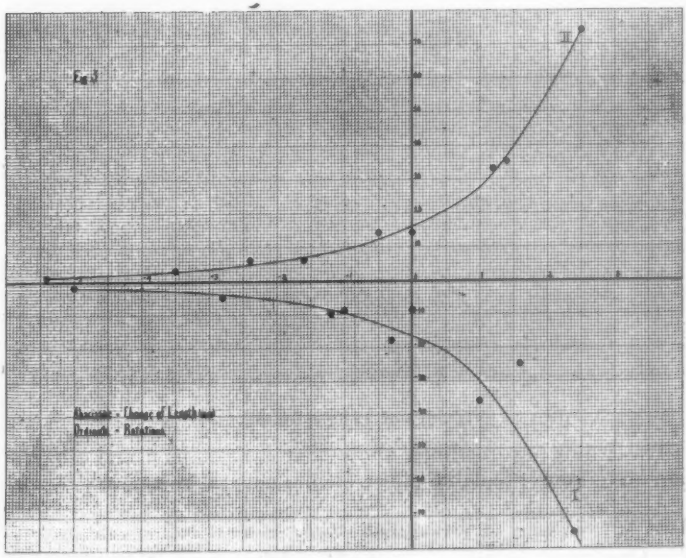
$$y = k\frac{1}{x}$$

introducing a few values for x and y from any of the curves shows such an equation to be entirely unsatisfactory.

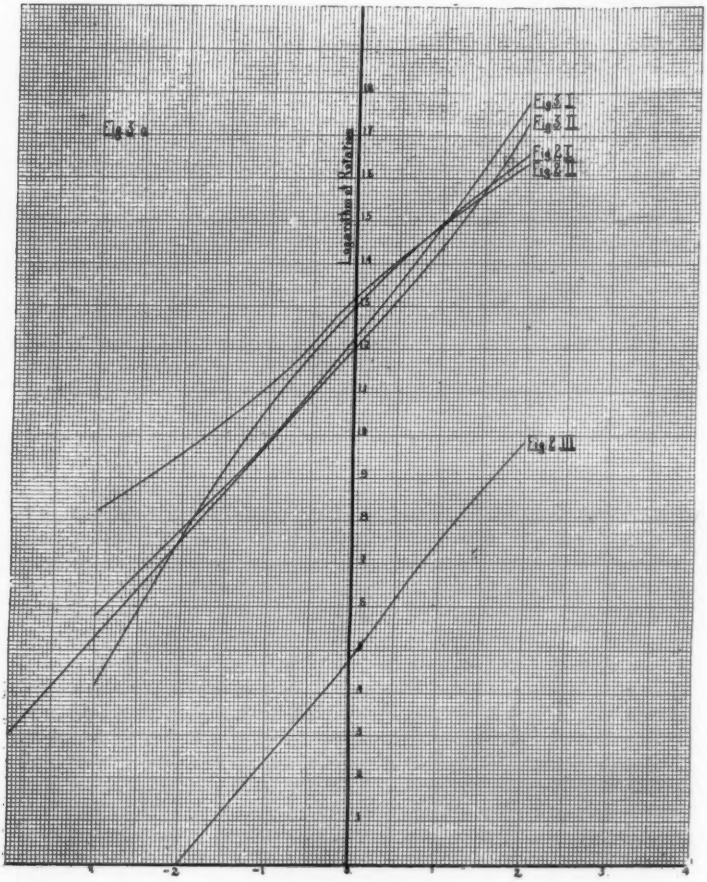
The above observations demonstrate that *the rotatory polarization of a jelly tube, subjected to a given twist, increases with longitudinal compression and decreases with longitudinal elongation, the change closely following an exponential law.*

Neglect of this condition was the chief cause of the great irregularities in the early work. When the lower clamp rested on the platform, *e*, it made an appreciable difference in the rotation which end of the jelly tube was first clamped, it being clamped in the one case when compressed and in the other when stretched by its own weight. The same tube was quite sure to give different results when taken out and replaced, for it could never be replaced under exactly the same strain. The first attempt to avoid this difficulty was to keep the measured length constant with clamps, but this gave little improvement.





In the final, vertical form of apparatus the lower clamp could be freely suspended from the jelly tube, simply guided by the ring *i*, and the twist was applied by the cords *x*, great care being taken to have them horizontal.



Change of Length (m.m.).

The following readings show that compression and elongation have no appreciable effect on the natural rotation.

Aug. 5.	Tube C 5.					
Change of length	0	1·7	3·6	0	−1·1	−3·3
Position of analyzer ..	86	87	87	86	87	86

Tube D 1.

Change in length	0	1·1	2·1	−1·5	−2·9	−5
Position of analyzer ..	85	85	85	86	85	35

Independent cylinders would not endure elongation or compression under large static twist sufficient time to determine the rotation.

Hydrostatic Pressure.—The lateral envelope and longitudinal stress having so great an influence, it was of interest to find the effect of hydrostatic pressure. A jelly tube was clamped under suitable twist by screws passing through an outer, larger, iron tube. This tube with the jelly tube inside was placed inside a still larger iron tube with carefully packed glass windows at the ends. Hydrostatic pressure was applied with an hydraulic pump provided with a pressure gauge.

July 23d. Tube C 3. The pressure is expressed in pounds per square inch.

Pressure	0	80	80
Rotation	32	30	31

July 24th. Tube C 4.

Pressure	0	120	0	160	0
Rotation	50	50	50	51	52

The above are typical examples of a series of observations which demonstrated that up to 160 lbs. per sq. in., *hydrostatic pressure does not affect the rotation.*

*Effect of Previous Strains.**—Relaxation is very conspicuous. If a jelly tube be subjected to prolonged twist the rotation decreases owing to the strain upon the jelly relaxing. For example:

June 25. Tube F 1.

Twist of −100 applied, rotation immediately after = 21
" 2 min. " = 18
" 2 hrs. " = 14

July 5. Tube F 2.

Twist of 120 applied, rotation immediately after = −21·
" 3 min. " = −17
" 10 " " = −17

If the rotation is read for a given twist and then a greater twist is applied in the same direction, on returning to the first twist the rotation has decreased owing to the increased relaxa-

* In the four species of relaxation effects the twist is counted from the original reading for zero twist. The variation in the rotation is of course due to change in the zero making the actual twist different from the stated apparent twist.

tion of the strain under the greater twist so that the actual final twist is less than the orginal. Similarly after a prolonged twist in the opposite direction the rotation for a given apparent twist increases, the actual twist being greater than before. Simply one of a great number of examples will be given.

June 24. Tube F 2.

Rotation for twist of 120 after prolonged twist of $0 = -16$
" " " " " $150 = -14$
" " " " " $-160 = -18$

If a twist has been maintained for a long time, on returning the tube to its original position for zero twist, an opposite rotation is sometimes observed owing to the jelly having relaxed so much that with the lower clamp in its original position for zero twist, there now is a considerable twist in the opposite direction. For example

June 24. Tube F 2.

Original position of analyzer for no twist = 86. After standing two hours under a twist of −100 which gave a rotation of 13, on apparently removing this twist the position of the analyzer was 87·5, showing a small negative rotation.

To eliminate these relaxation disturbances, (1) a uniform short time (from $\frac{1}{2}$ to 2′ depending upon the tube) should elapse between the application of the twist and the reading of the rotation, that a practically steady state may be reached; (2) the lower clamp should be free, i. e., suspended from the jelly tube as described above, and the twist maintained by the cords, that the position finally taken by the freely hanging lower clamp may be observed before and after each twist is applied.* It is necessary to wait a few minutes in determining the zero, for the approach to a position of equilibrium is asymptotic.

July 11. Tube C 4.

Initial position of lower clamp for no twist = 67.

The first row gives the times after a weight of 180^g was applied to each cord, the second row the corresponding position of the lower clamp.

30″	60″	90″	120″
287	285	284	283

Weight removed

30″	60″	90″	120″
61	63	64	64

* This method of determining the true zero, i. e., the position of the lower clamp for no twist, assumes that the rubber tube relaxes the same amount for a given twist as the jelly inside. While making observations described later upon the rigidity of independent cylinders and of rubber tubing, the relaxation of this rubber tubing for a given twist was found to be approximately the same as that of jelly for the same twist.

This asymptotic approach to equilibrium is similar to that observed with metals, only more conspicuous.

Relaxation disturbances can be avoided as described above. There is, however, another effect of the previous history. *A prolonged preceding twist increases the rotation for an immediately following less twist in either direction* but has little influence on a greater twist.

(Relaxation effects eliminated, observations in chronological order.)

July 16. Tube C 3.

Twist	90	120	100	120	90	120
Rotation	−9	−25	for 10′	−29	−12	−27
Twist (cont.)	90	−100	120	90	90	
Rotation "	−11	for 10′	−26	−10	−7	

July 17. Tube C_2.

Twist	90	120	−100	90	120	100	90	120	90
Rotation .	−7	−24	for 15′	−11	−22	for 16′	−11	−24	−7
Twist (cont.)	120	100	120	90	−100	120	90	90	120
Rotation "	−24	for 18′	−27	−10	for 21′	−24	−9	−9	−26

This effect is not due to a simple disturbance of the jelly; a prolonged strain is necessary; alternate twists of short duration have little effect.

July 16. Tube C_2.

Twist	90	16 alternate twists		90	90
Rotation	−9	of ±120 in rapid succession		−9	−9

July 17. Tube C_2.

Twist ...	90	120	16 alternate twists	120	90
Rotation	−9	−26	of ±100 in rapid succession	−26	−8

As illustrated above, this effect of a previous twist rapidly dies away. Therefore to avoid this disturbance small twists should precede greater and in general some time should elapse between observations.

If we make alternate twists in succession, counting the twist from a constant zero, we notice both effects of previous history. A typical case is the following:

June 26. Tube F 1.

Twist	100	−100	100	−100	100
Rotation	−19	10	−25	11	−28
Twist (cont.) ...	−100	100	−100	100	−100
Rotation " ..	12	−28	13	−28	13

Theoretically the relaxation should make the odd rotations, −19, −25, etc., increase, while the even, 10, 11, etc., should slightly decrease. The increase of the latter is due to the other effect of a previous twist, which also causes the odd rotations to increase faster than they would by simple relaxation.

Under *prolonged stress* the rotation increases in contrast to the decrease with prolonged strain.

July 21. Tube C_4. Weight of -180^g applied to cords at 10·18.

Time.....	10·20	10·30	10·35	10·37	10·45
Rotation....	11	14	$+130^g$ applied	−7	−13

July 22. Tube F 1. 180^g applied at 11·13.

Time....	11·15	·20	·25	·30	·35	·50	12·08	
Rotation	−25	−28	−33	−35	−38	−38	-180^g	applied

Time (cont.)..	12·08	·11	·21	·37	
Rotation " ..	34	39	52	53	

The stress being constant, the actual strain is constant but the prolonged state of strain increases the rotation.

Influence of Temperature.—As would naturally be expected, the *rotatory polarization decreases with rise of temperature*, owing to decrease of strain with increased relaxation and a more fluid condition of the jelly. Throughout this work it has been noticed that the softer and more fluid the jelly the less the rotation.

Aug. 6. Tube E 1. Twist of 90.

Temperature	23°	36	37
Rotation.....	−31	−25	−10

Tube E 6. Twist of −90.

Temperature ..	23°	38	38	23	Repeating 23
Rotation.....	26	15	3	4	Twist 21

The jelly tube was loosely surrounded by an electric heating coil. A thermometer between the jelly tube and the coil gave the temperature.

From the above we should expect that with a given jelly tube, the lower clamp being freely suspended from it and the cords which apply the twist being horizontal, the position of the lower clamp for zero twist being read before and after each twist, sufficient time being allowed for the jelly tube to approximately reach zero twist, a uniform, short time being allowed after the twist is applied before the rotation is read, and a considerable time intervening between a large twist and a succeeding small twist, the temperature being approximately

constant—under these conditions we should expect the rotation for a given twist to be constant and definite. Such is approximately the case, as is illustrated by the following observations, where these precautions have been carefully observed:

RELATION BETWEEN TWIST AND ROTATION.

July 21, A. M. Tube D 3. Length of jelly = 3·0^{cm}. 1′ delay after twist was applied and commencement of readings of rotation.

Twist	−90	90	−110	110	−120	120	−130	130
Rotation..	1	−4	2	−13	2	−18	2	−26
Sum	5		15		20		28	

July 21, P. M. After tube has been removed from the instrument, turned end for end and replaced.

Twist ..	−60	60	90	−90	110	−110	120	−120	130	−130
Rotation	−1	1	−6	0	−13	0	−21	1	−26	1
Sum ...	2		6		13		22		27	

July 22, A. M. After tube has been taken out, turned end for end, and replaced.

Twist ..	−60	60	−90	90	−110	110	−120	120	−130	130
Rotation	0	0	2	−4	2	−11	3	−17	4	−22
Sum	0		6		13		20		26	

On account of change of zero due to relaxation the actual twists of the jelly, when the rotation was read, were 56, 83, 101, 109, and 118 respectively.

July 22. Tube D 4. Length of jelly = 3^{cm}. 2′ delay between twist and reading of rotation.

Twist	60	−60	90	−90
Rotation....	−8	2	−39	9
Sum.....	10		48	

The actual twists were 56 and 83.

July 22. Tube F 1.* Length of jelly = 4^{cm}. 1′ delay between twist and reading.

Twist	−60	60	−90	90	−110	110
Rotation..	1	−1	3	−1	6	−3
Sum.....	2		4		9	

Twist (cont.)	−120	120	−135	135	−150	150
Rotation "	8	−4	11	−6	19	−15
Sum "	12		17		34	

* These readings differ widely from those given for this tube on previous pages. The explanation is that in the earlier observations the lower clamp rested on the platform *e* and the jelly tube was longitudinally compressed relatively to what it was here when stretched by the freely hanging lower clamp.

The actual twists were 57, 85, 104, 112, 125, 139 respectively.

Aug. 9. Tube 11. Length of jelly = 3cm. ½′ delay between twist and reading.

Twist	−60	60	−90	90	−110	110	−130	130
Rotation .	0	0	1	−1	1	−2	4	−5
Sum	0		2		3		9	
Twist (cont.)	−150	150	−170	170	−190	190		
Rotation "	4	−13	6	−29	16	−57		
Sum " ...	17		35		73			

The actual twists were 57, 86, 104, 123, 142, 160, 178.

To illustrate the accuracy of the work, the observations upon tube (43) will be given in full.

Aug. 11. Tube 43. Length of jelly = 3cm. ½′ delay between twist and reading.

Apparent twist	0	90	−90	120	−120	150	−150	170	−170
Corrected twist	0	84	−84	112	−112	140	−140	158	−158
	79	83	73	85	68	90	58	100	50
	81	81	77	86	71	97	61	101	50
	82	85	79	87	74	89	63	94	53
	83	84	81	83	75	90	65	98	56
	82	82	77	84	69	92	63	95	53
	81	83	79	87	73	94	60	100	54
	80	81	73	85	68	93	61	100	54
	80	81	74	81	69	92	60	103	50
Means	81	83	77	85	71	92	61	100	52
Rotation		−2	4	−4	10	−11	20	−19	29
Sum		6		14		31		48	

The natural rotation of all the above tubes was about 2·7 per cm.

Dissymmetry in Rotations.—The dissymmetry in the two directions of rotation for apparently the same numerical twist has been very conspicuous. This is partly due to uncertainty of the true position of the lower clamp for zero twist. A slight error will make the actual twist applied in one direction differ from that applied in the other direction by twice this error, and the difference in the rotations will be still greater. The principal cause is probably dissymmetry in the rubber tube. In most of the cases where the dissymmetry was marked the moment was measured which was required to produce a given twist, and in every case it was found that a greater moment was required for a twist in the direction which gave the greater rotation, i. e., for a given twist more force was

applied to the jelly tube, probably in the form of greater constraint upon the jelly by the rubber tube. From the previous results upon the effect of an envelope, the greater rotation would be expected.

For example :

July 21. Tube D 3.

Negative rotations greater.

80^g	pull on cords	gave a twist of		64
−80^g	"	"	"	−65
200^g	"	"	"	178
−200^g	"	"	"	−183

Here we see greater rigidity for positive twists, which produce negative rotations.

Tube D 4.

80^g	gave	47
−80^g	"	−49
150^g	"	91
−150^g	"	−96

} giving a similar result.

The dissymmetry is not due to the natural rotation, as the excess is as likely to be for one direction as for the other.

As neither rotation is more important, we will study the average, or sum of the two rotations. The observations with tube D 3 are plotted in fig. 4. The observations upon tubes D 4 and F 1 are given in fig. 5 and for tubes 11 and 43 in fig. 6. The abscissæ are twists and the ordinates rotations (sums).

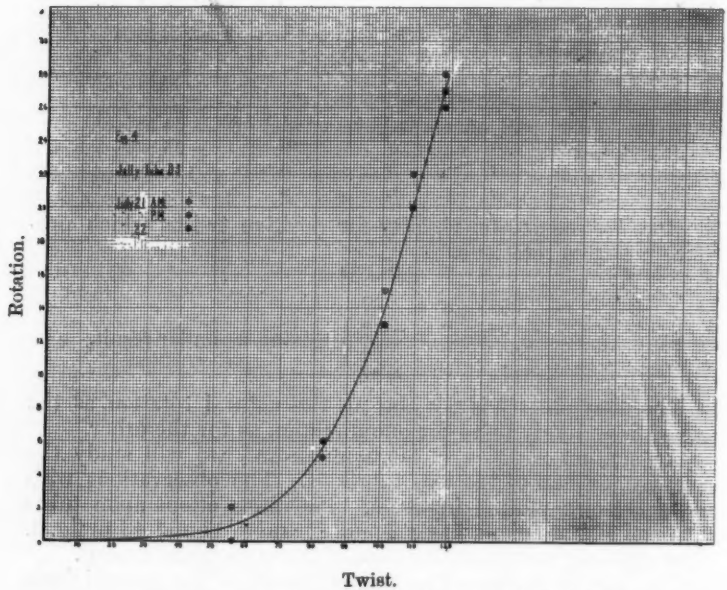
The curves resemble exponential curves of the general form $y=cx^n$ or $log\ y=log\ c+n\ log\ x$. To determine whether they are such, and if so, of what power, I have plotted in fig. 6*a* the logarithms of the twists and rotations. All of these curves approximate to straight lines, at least for the greater twists, and the inclination of these straight lines is very close to four, giving the very interesting result that, when other conditions are kept constant, *the rotation is closely proportional to the fourth power of twist.*

The curves of the sums of two rotations will have the nature of each one separately, for if the law of one be $y_1=k_1x^n$ and of the other $y_2=k_2x^n$, the equation of the sum will be the same power of the twist, or, $y_1+y_2=(k_1+k_2)x^n$.

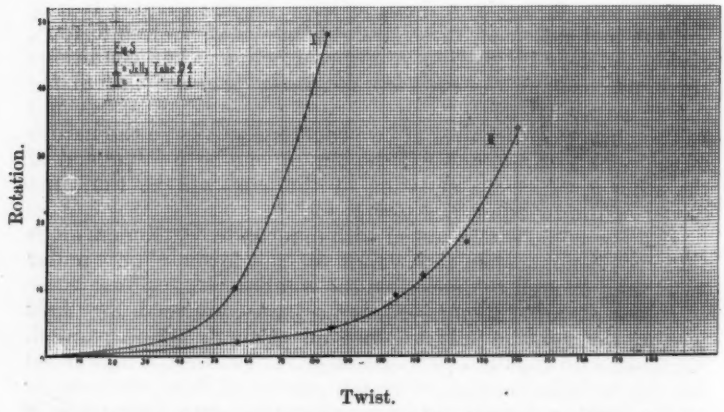
The law could not be tested with independent cylinders since they would not sustain the weight of the lower clamp under twist long enough to determine the rotation.

Plane Parallel Light.—Since no lenses are used, the light passing through the jelly will not be perfectly plane parallel. To make sure that the phenomena are not caused or influenced by this fact (for instance, through reflections from the interior of the rubber tubing, which however is quite dark), a jelly tube was clamped under twist and examined with strictly plane

parallel light from an arc light lantern, which passed in succession through polarizer, biquartz, jelly tube and analyzer.



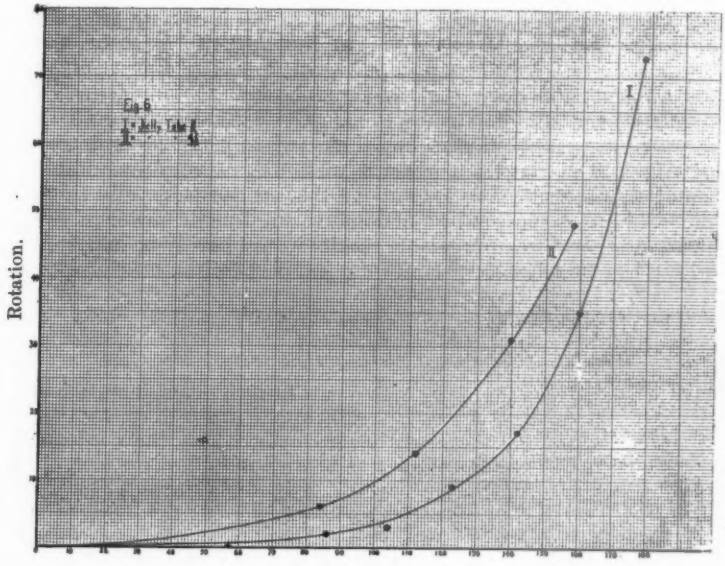
The position of the analyzer for the untwisted jelly was 35. When the jelly was given a certain unmeasured positive twist

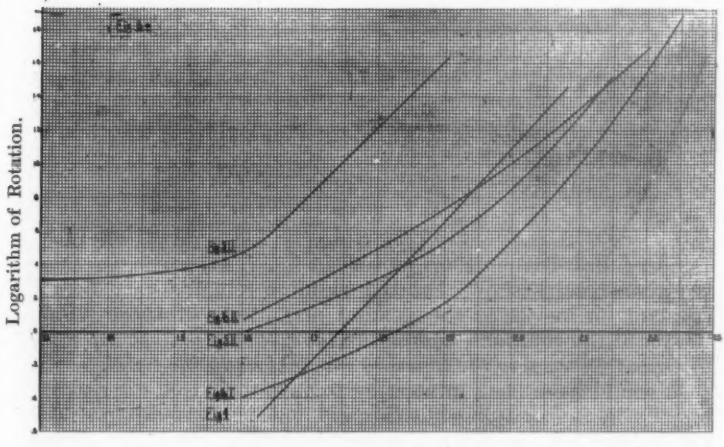


the position of the analyzer was 59 showing a rotation of −24. When the jelly had a certain negative twist the analyzer read 10 showing a rotation of 24.

Glass.—A glass rod was secured from the John A. Brashear

Co., Ltd. of Allegheny, Pa., 11·9^{cm} long, 0·506^{cm} in diameter, with carefully polished ends, perfectly transparent and show-





ing no trace of strain when examined between crossed Nicols. Circular wood blocks were carefully fitted and glued around the ends. These were fixed in the clamps of the apparatus

described above. The amount of twist was measured by means of a mirror attached to the lower wood block and a distant telescope and horizontal scale. Successive twists in both directions were applied up to a twist of 3°·1 produced by weights of 2030^{g} applied by the cords to the opposite sides of the lower clamp of 4·58^{cm} diameter.* On applying this twist in the opposite direction the glass rod broke. No evidence of rotatory polarization was observed. Observations reported in a previous paper† indicated that twist produces rotatory polarization in glass, but glass is obviously a very unsuitable material, since we have seen above that at least in jelly tubes the rotation is closely proportional to the fourth power of the twist and therefore appreciable results would hardly be expected with glass, which only permits the smallest twists.

The *rigidity* of these jellies was carefully studied.

Relation between Twisting Couple and Twist.

Mar. 11. Independent jelly cylinder. Length = 5·6, diameter = 2·0. Moment of couple = weight applied to each cord × 4·58, the diameter of the lower clamp upon which the cord was wound. The same couple was applied in both directions.

Moment	22·8	45·8	96	169	238	306	376	466	561
−Twist	9		40	73	102	129	147	179	207
+Twist	11	21	44	73	102	128	152	186	209

These measurements are plotted in fig. 7, I.

Independent cylinders could not endure such twists if the cylinders were vertical supporting the lower clamp; a modified form of apparatus was used in the above measurements, in which the cylinder was horizontal and the movable clamp rested upon friction wheels similar to those of an Atwood's machine.

July 21. Independent jelly cylinder; (approximate) length = 8, diam. = 2·0.

Moment	22·6	48·7	75	101
+Twist	33	69	110	145
−Twist	32	71	111	148 (broke)

These measurements are plotted in fig. 7, II.

These results show that the rigidity remains very nearly constant for twists of the general magnitude of those which produced the rotations, and before *the rotation is in practically the same relation to the twisting moment as to the twist.*

It would have been interesting to have measured the rigidity of jelly in rubber tubes but this did not prove feasible. The soft rubber tube is so much more rigid than even the stiffest

* These figures give as the rigidity of this glass $2{\cdot}97 \times 10^{11}$.

† This Journal (3), viii, 89, 1899.

transparent jelly that practically all the moment applied was applied to the former.

July 22. Jelly tube 44.

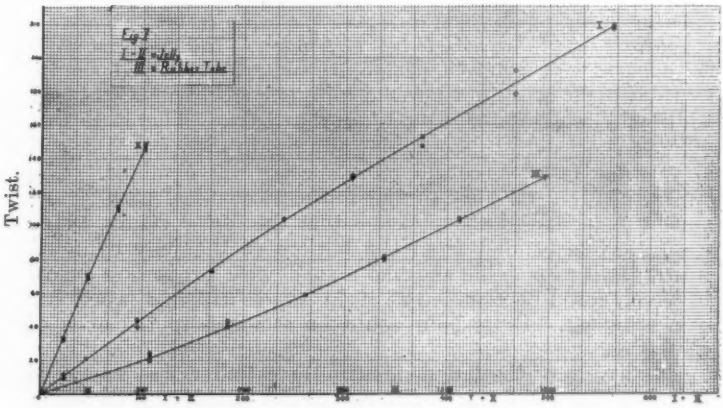
Moment applied	366	−366
Twist	47	−49

Identically same tube empty.

Moment	366	−366
Twist	59	−55

Same tube filled with water.

Moment	366	−366
Twist	59	−57



The unavoidable uncertainty in such measurements is so large a fraction of the difference that no extended observations were made.

Rigidity of Rubber Tubing.—Since the rubber envelope plays so important a part, the relation between couple and twist was investigated for a rubber tube similar to those filled with jelly, but filled with water that the interior might exert a similar resistance to compression as jelly without offering any rigidity.

April 9, '01. 4^{cm} of water.

Moment	325	555	784	1015	1245	1488
+Twist	20	40	59	80	104	
−Twist	24	43	59	81	103	128

These readings are plotted in fig. 7, III. *The rubber tube closely follows Hook's law within this wide range.*

Does the rigidity have any of the peculiarities of the rotatory polarization?

Rigidity and Previous History.—The rigidity of the jelly does not seem to be influenced by a previous prolonged twist.

Aug. 4. Independent jelly cylinder. Length = 7·8. Cross section = 3·60$^{cm^2}$.

Moment of couple.....	31·3	−31·3	−31·3	31·3	31·3
Twist.....	48·5	−44	−45	47·5	48

Twist of 80 applied for 25′. Immediately after—

Moment	31·3	31·3	−31·3	−31·3
Twist	48	47	−45	−45

Twist of −80 applied for 50′. Immediately after—

Moment	−31·3	31·3	31·3	−31·3	31·3
Twist	−45	46	48	−45	46

Other series of observations gave the same result.

Rigidity and Longitudinal Extension.—Independent jelly cylinders would endure a prolonged twist if stretched simply by the weight of a light lower clamp, but would not hold any additional weight for stretching the jelly. Therefore the vibration method of determining the rigidity was adopted, and after some failures, considerable success was obtained. The apparatus used was very similar to the mechanical part of the apparatus described above except that the lower clamp, which was freely suspended from the bottom of the jelly cylinder, was as light as possible and had a steel wire projecting below to which could be clamped at right angles either a wood bar or a brass bar. Brass bobs could be attached to the ends of the latter.

The length of the independent jelly cylinder was measured between the relatively inflexible rubber clamps at the ends. The cross section was obtained as follows: Two points were marked on the jelly with aniline ink. The distance between these marks was measured when, first, the jelly was free from any attachments; second, when stretched by the lower clamp; third, with the wood bar additional; fourth, with the brass bar in place of the wood bar, and fifth with the brass bar and bobs. The jelly cylinder, free from any attachments and with carefully cut ends, was placed in a graduated glass sufficiently filled with benzine (which is inert towards the jelly) to cover the jelly. From the change in level of the benzine the volume of the jelly was determined, which with the measured length gave the cross section. The proportional change of length for each weight added being known, the cross section for each weight was determined.

$$n = \frac{8\pi Il}{r^4 T^2}$$

I = moment of inertia of mass, attached to lower end of cylinder; T = complete period of vibration, which was measured

with a stop-watch reading to fifths of seconds; l and R are the length and radius respectively of the jelly cylinder.

Data.

Lower clamp; weight 41ᵍ. moment of inertia=50ᵍ ᶜᵐ².
Brass bar; weight=87, length =20·1, radius=0·375, mom. of inertia=2940
Wood bar; " =11, " =17·7, " =0·25, " " =287
Bobs; " =42, " mean distance from axis =9·05, " " =3450

Aug. 5. Independent jelly cylinder.

Total length of jelly immersed in benzine	13·95
Volume	51·90
Cross section	3·72
Distance between rubber clamps, no attachments	15·00
" " aniline marks "	10·50
" " " clamp + wood bar attached	10·98
" " " " brass "	11·37
" " " " " + bobs "	11·83

Wood bar attached.

$$I=337 \quad l=\frac{10\cdot98}{10\cdot50}\,15\cdot00=15\cdot7 \quad \pi r^4=\frac{10\cdot50}{10\cdot98}\,3\cdot72=3\cdot55$$

Times of 10 vibrations: 7·2, 7·4, 7·4, 7·6, 7·4. Mean $T=0\cdot75$
$n=1\cdot8\times10^5$.

Brass bar attached.

$$I=2990 \quad l=16\cdot2 \quad \pi r^4=3\cdot44.$$

Times of 20 vibrations: 40·6, 40·6, 40·4, 40·4, 40·6. Mean $T=2\cdot03$
$n=2\cdot5\times10^5$.

Brass bar + bobs attached.

$$I=6440, \quad l=16^g, \quad \pi r^4=3\cdot30.$$

Times of 10 vibrations: 37·6, 37·6, 37·6 (broke)
$n=7\cdot6\times10^5$.

The rigidity was also successfully measured statically for a shorter length of this same cylinder when stretched by clamp + wood bar.

$$n=\frac{2Ml}{\pi r^4\theta}$$

where M=moment of couple required for the twist θ.

$l=10\cdot8 \quad \pi r^4=3\cdot55 \quad M=13\cdot980\cdot1\cdot74$ (1·74=diameter of part of lower clamp upon which the cord supporting the weight of 13ᵍ was wound). Mean value of $\theta=\frac{44}{57\cdot3}$.

$n=1\cdot8\times10^5$ (exact agreement).

Aug. 8. Independent jelly cylinder, (made with a different gelatine from the cylinder of Aug. 5). Omitting details, when the length was 10·40 the rigidity was $1\cdot06\times10^5$ and when the length was 10·83 the rigidity was $1\cdot06\times10^5$.

These results indicate that *the rigidity of jelly increases with longitudinal extension.*

Dispersion.—No success was attained in measuring the dispersion, i. e., the variation in rotatory polarization for light of different wave lengths.

The biquartz could not be used since this is cut for some particular color, in this case to rotate the mean yellow through 90°, giving rise to the "sensitive tint" when placed between parallel Nicols. With simply two Nicols the dispersion was evident. If the analyzer and polarizer were crossed and the jelly introduced, on slightly turning the analyzer the field became green, showing the extinction of the longer waves, and on turning farther in became red, showing the extinction of the shorter waves. When a twist was applied this dispersion was still evident and the positions for the extinction of the different colors seemed farther apart, but no quantitative measurements could be made. When the jelly was twisted the coloration of the fields was irregular. Attempts were made to test the light emerging from the analyzer in both a direct vision spectroscope and an ordinary spectroscope. As the analyzer was rotated, successive parts of the spectrum did not perceptibly fade out, but near certain positions the whole spectrum gradually diminished in brightness until a mininum was reached, and then increased in brilliancy. The position for this minimum could only be determined roughly, but it essentially agreed with the portion of the plane of polarization of yellow light as determined with the biquartz.

Aug. 6. Tube 31. 3^{cm} of jelly.

Position of analyzer; with biquartz = 225, without biquartz for greatest darkness = 226, with the addition of a direct vision spectroscope, for greater general darkness of spectrum = 225.

Twist of 100.

Position of analyzer; with biquartz = 243, without biquartz = 242, with *d.v.s.* = 241.

Twist of −140.

Position of analyzer; with biquartz = 207, without biquartz = 207, with *d.v.s.* = 205.

Quartz plates introduced produced a dark band in the appropriate part of the spectrum, showing that the apparatus was properly adjusted.

Probably dispersion is present and very likely it follows the law of inverse squares of the wave length. The biquartz locates with great sensitiveness the mean position of the plane of polarization of yellow light. Owing to the complicated strains introduced with the twist, there is probably always yellow light polarized in all neighboring azimuths, of only little less intensity and similarly for other colors. Moreover, the jelly appears much more transparent for yellow light than

for other colors. These facts, coupled with the irregularities in location of the plane of polarization of yellow light in different azimuths, as illustrated above where full sets of readings are given, make it natural that the dispersion should not be very clear.

Theory.

With hesitation I suggest the following imperfect theory. In a section of a twisted cylinder, perpendicular to the axis, along any line, whether straight or curved, there is nothing to distinguish one direction of motion from the opposite direction of motion. Therefore for two rays circularly polarized in opposite directions, traversing a twisted cylinder parallel to the axis, the conditions are identically the same in the wave front. Therefore the only difference can be in the lines along which the two opposite disturbances are propagated. The successive points disturbed by a positive circularly polarized ray lie at any instant on a negative spiral and vice versa. Is there anything to distinguish two opposite spirals parallel to the axis of a twisted cylinder? If the side of a spiral farthest from the axis of the cylinder has the same direction of twist as the adjacent part of the cylinder, the side of the spiral nearest the axis must have the opposite direction, and so there would be no distinction between the spirals were it not for the important fact that in a twisted cylinder the stresses and strains increase as we leave the axis radially, and therefore the outside of a spiral has a predominating influence.

Suppose the twist of a cylinder is positive, counting direction the same as for the rays. Any tangential (perpendicular to a radius) square in the cylinder with two of the edges perpendicular to the axis, will be distorted into a rhombus, the axes of strain being the diagonals. Therefore there will be stretching along the outside of the positive spiral and compression along the outside of the negative spiral. We may expect compression to decrease the velocity, for, in general, the denser a body, the slower light is transmitted through it. If this be so, we should expect to see the ray corresponding to the positive spiral to be transmitted faster than the ray corresponding to the negative spiral, or the cylinder having a positive twist and the positive spiral, corresponding to a negative circularly polarized ray, a negative circularly polarized ray will have the greater velocity and the plane of polarization will be rotated in a negative direction. Or, torsion should produce rotatory polarization in the opposite direction to the twist, which agrees with the experimental facts.

The effect of pressure upon the refractive index of jelly was investigated. Pressure was applied to jelly between two glass plates, forming a prism, by varying the angle of the plates. No

conclusive results were obtained owing to the great double refraction, introduced by the compression. Jelly is very incompressible.*

I do not see how in the above theory to account for the effect of the envelope unless the envelope affords a constraint preventing the jelly from yielding under the strains produced by the twist, the more perfectly these strains are maintained the greater being the rotatory polarization.

Consider the above mentioned rhombus into which the square has been distorted. The distortion will bring the diagonal along which there is compression nearer the axis than the other diagonal. Therefore longitudinal compression will increase the compression along this diagonal more than it will decrease the elongation along the other diagonal, and therefore we should expect the rotatory polarization to be increased, which agrees with the experimental facts. Similarly we should expect elongation to decrease the rotatory polarization, which it does. On this theory we are not surprised that hydrostatic pressure produces no effect, since it is perfectly symmetrical and homogeneous.

This rotatory polarization might be expected in a general way according to many theories of rotatory polarization which require rotatory polarization where there is such dissymmetry present as in a twisted body.

Conclusions.

The following are the most important facts added to those established in previous papers.

1. For a given twist, the rotatory polarization is very much increased by an envelope about the jelly.

2. The rotatory polarization of jelly twisted in a rubber tube is very much increased by longitudinal compression, and decreased by longitudinal elongation, closely following an exponential law.

3. It is not affected by hydrostatic pressure.

4. It is, to some extent, dependent upon the previous history of the jelly.

5. When these disturbing influences are kept constant the rotatory polarization is quite definite for a given twist and,

6. The rotation is closely proportional to the fourth power of the twist.

7. The rigidity of the jelly increases with longitudinal elongation.

Finally, a theory has been suggested for explaining some of the above facts.

I wish to acknowledge my indebtedness to Prof. A. Wilmer Duff for many valuable suggestions and criticisms.

Worcester Polytechnic Institute, Worcester, Mass.

*P. von Bjerkén, Wied. Ann., 1891, p. 817.

Art. XXXVII.—*The Use of the Zinc Reductor in the Estimation of Vanadic Acid;* by F. A. Gooch and R. D. Gilbert.

[Contributions from the Kent Chemical Laboratory of Yale University—CXVI.]

The reduction of vanadic acid to the condition of vanadium tetroxide preparatory to estimating it by titration with potassium permanganate is generally accomplished by the use of sulphurous acid or hydrogen sulphide. The more convenient method of treatment by zinc and free acid is not directly applicable on account of the irregular reduction of vanadic acid under the conditions to a stage approximating that of the dioxide, as was first shown by Czudnowicz.* The work herein described is the result of an attempt to find a reliable method for bringing the product of reduction of vanadic acid by zinc and acid definitely to the condition of the tetroxide, in order that the reductor so useful in the preparation of salts of iron for titration by potassium permanganate may be made similarly applicable in the estimation of vanadic acid and its salts.

A very convenient form of reductor† was made as follows: The contracted end of a piece of glass tubing, 2^{cm} in inside diameter and 50^{cm} long, was sealed to a stop-cock prolonged in a smaller tube, $0{\cdot}5^{cm}$ in inside diameter, to a length of 24^{cm}. At the point of contraction in the larger tube was placed a piece of platinum gauze, next to this a mat of fine glass wool 2^{cm} in thickness, and upon the last a column 40^{cm} long of amalgamated zinc of a size to pass a sieve of eight meshes to the centimeter. The smaller tube passed through a rubber stopper fitted to a vacuum flask and the last was connected through a pressure regulator with the vacuum pump. In using this apparatus the pump was started, the regulator set to give a pressure in the flask less than the outside pressure by an amount equal to 20^{cm} of water, the reducing column of zinc was warmed by passing through it hot distilled water followed by 100^{cm^3} of hot 1 per cent sulphuric acid, and then the solution of the salt of vanadic acid to be reduced was gradually drawn through the zinc in small portions, alternating with portions of the 1 per cent sulphuric acid amounting to 100^{cm^3}. Finally, the column was washed down with 100^{cm^3} more of the dilute sulphuric acid and about 250^{cm^3} of hot distilled water. Throughout the entire series of operations care was taken to keep the zinc covered with liquid and so out of contact with the air.

The lavendar solution collected in the flask contains vanadium dioxide, which when exposed to the action of a current of air takes, as Roscoe has shown,‡ the blue color of the

* Ann. Phys., cxx, 39 (1863).

† Described in Blair's Chemical Analysis of Iron, p. 93 (edition of 1902).

‡ Ann. Pharm. Suppl., vi, 98 (1868).

tetroxide. The first attempts, therefore, to bring about definiteness of condition were made along the lines of Roscoe's observation. The solutions obtained in the receiving flask were treated by air at various temperatures and for various lengths of time, and then, after heating to 80°, were titrated with nearly $\frac{N}{20}$ potassium permanganate standardized by reference to $\frac{N}{20}$ arsenious oxide.

This most exact method of standardizing the permanganate was carried out by adding a convenient volume (43$^{cm^3}$) of the permanganate to a solution of potassium iodide (3 grm.) acidulated with sulphuric acid (3$^{cm^3}$ of the 1 : 1 acid) contained in a glass-stoppered flask fitted with a funnel tube and trapped, introducing through the funnel tube an excess of a standard solution of $\frac{N}{20}$ arsenious oxide, neutralizing with acid potassium carbonate, and titrating in presence of starch with iodine also standardized against the arsenious oxide.

In blank experiments made from time to time with the reductor it was found that the reading color developed in the acid solution only after the addition of 0·2$^{cm^3}$ of the standard permanganate, and this correction, due to traces of iron in the zinc and the considerable volume of the solution, was applied in the experiments in which the vanadium salt was treated. In our experiments ammonium vanadate was the salt of vanadic acid employed and the sample with which we worked contained 76·66 per cent of V_2O_5, as determined according to the iodometric method of Holverscheit.*

The results of some attempts under most favorable conditions to effect the oxidation of the reduced trioxide to the condition of the tetroxide by the action on air are given in Table I. These show plainly that, although the oxidation by air appears to proceed rapidly at the outset, the complete conversion of the lower oxides to the tetroxide by such action takes place with too great slowness and uncertainty to form the basis of a reliable and rapid quantitative method.

TABLE I.

Time of treatment by air. min.	Temperature.	V_2O_5 taken. grm.	V_2O_5 found by titration with $KMnO_4$. grm.	Error. grm.
75	56°—28°	0·0767	0·0778	+0·0011
75	60°—29°	0·0767	0·0805	+0·0038
75	48°—29°	0·0767	0·0829	+0·0062
75	†100°—	0·0767	0·0772	+0·0005
75	†100°—	0·0767	0·0769	+0·0002

* Inaug. Diss. Berlin, 1890, p. 49.

† Brought twice to the boiling point during this interval.

The action of the molecular oxygen of the air is obviously insufficient to bring about the complete oxidation of the lower vanadium oxides in acid solution to the condition of the tetroxide within a reasonable time, and ordinary oxidizers carry the action too far, oxidizing the tetroxide as well as the lower oxides. We have found, however, that silver oxide and silver salts will supply oxygen in a condition of activity sufficient to affect the lower oxides easily while leaving the tetroxide intact. Silver sulphate appears to be the most convenient form in which to use the silver compound.

In making our experiments with silver sulphate the solution of the vanadic acid was treated in the reductor in the manner described except that the receiving flask was charged at the outset with a saturated solution of silver sulphate —100$^{cm^3}$ in each of the first six experiments; 300$^{cm^3}$ in the last two. The contents of the flask were boiled and then filtered upon asbestos in a perforated crucible. The solution, now about 700$^{cm^3}$ in volume, was heated again to the boiling point and titrated with $\frac{N}{20}$ potassium permanganate. When the reduced solution issuing from the reductor meets the silver sulphate a muddy deposition of finely divided silver begins; but upon boiling the mixture the metallic silver gathers into a single spongy mass and leaves the solution so clear that were it not that spongy silver is easily acted upon by the permanganate* the titration might be made without previous filtration.

TABLE II.

V_2O_5 taken. grms.	$KMnO_4$ required, nearly $\frac{N}{20}$. cm^3.	V_2O_5 found. grms.	Error. grms.
0·0767	17·	0·0770	+0·0003
0·0767	17·04	0·0771	+0·0004
0·0767	17·05	0·0772	+0·0005
0·0767	16·96	0·0768	+0·0001
0·0767	16·98	0·0769	+0·0002
0·0767	17·	0·0770	+0·0003
0·1918	42·9	0·1942	+0·0024
0·1918	42·7	0·1933	+0·0015

The results of these experiments are given in the accompanying table. For the smaller amounts of vanadium the determinations are accordant and exact. The wider variations in the last two experiments are probably due to the difficulty of catching the pink end reaction in presence of the reddish yellow color which appears as the vanadic acid is formed in considerable amount. This is a difficulty inherent in the permanganate process of titration when large amounts of vanadic acid are involved.

* Giles: Chem. News, xv, 204 (1867). Otto van der Pfordten: Ber. d. d. Chem. Ges., xx, 3375. Friedheim: Ber. d. d. Chem. Ges., xx, 2554.

Art. XXXVIII.—*On the Composition of some Canadian Amphiboles;* by B. J. Harrington.

The writer is indebted to the Rev. W. P. Borhart, B.A., for specimens of a beautiful variety of amphiboles from the township of Grenville in the Province of Quebec. It had been mistaken for garnet notwithstanding its characteristic amphibole cleavage and optical characters. The specimens received are all massive and most of them show, in addition to eminent prismatic cleavage, a jointed structure, the jointage planes making various angles with the cleavage planes. The color is reddish-brown and the mineral shows a degree of transparency not commonly found in the species. Flakes obtained by cleavage exhibit an extinction angle of 16°. The specific gravity was found to be 3·110 at 15° C. and the hardness 6 or a little over. In composition the mineral is interesting on account of the large proportion of fluorine which it contains. The presence of this element has been observed in many amphiboles but as a rule in much smaller quantity. The quantitative analysis of a specimen of the mineral gave the following results:—

Silica	45·50
Titanium dioxide	0·68
Alumina	12·25
Ferric oxide	0·28
Ferrous oxide	0·75
Manganous oxide	0·11
Lime	13·31
Magnesia	20·63
Soda	2·76
Potash	1·76
Water	0·40
Fluorine	2·80
	101·23
Oxygen equivalent to fluorine	1·17
	100·06

Another specimen gave 2·93 per cent of fluorine, a larger proportion of this element than has been observed in any other amphibole, so far as the writer is aware. It was estimated by Rose's method, and on converting the calcium fluoride into sulphate the amount obtained in each case agreed almost exactly with the theoretical. The water was estimated directly by fusing in a platinum boat with the mixed carbonates of sodium and potassium in a current of dry air and collecting in a chloride of calcium tube. In the dry atmosphere

of a Canadian winter, potassium carbonate can be used with perfect safety. The combustion tube was protected by platinum foil, as recommended by Penfield, and heated by means of a blast-lamp. The titanium was estimated colorometrically.

In a general way the composition of the Grenville amphibole resembles that of a bright green variety from Pongas in Finland analyzed by Rammelsberg (I) and also one from the same place analyzed by Bonsdorff (II). Their results were as follows :*

	I	II
Silica	46·12	46.26
Alumina	7·56	11·48
Ferrous oxide	2·27	3·48
Manganous oxide	....	0·36
Lime	13·70	13·96
Magnesia	21·22	19·03
Soda	2·48	....
Potash	1·29	....
Water	1·10	....
Fluorine	2·76	2·86
	98·50	97·43
Sp. gr.	3·104	....

Another Canadian amphibole which has been analyzed is that occurring in the essexite of Montreal, a rock constituting portions of the mountain. The specimen examined was from the coarse-grained rock found in the Protestant cemetery and its separation from the other constituents was effected in part by means of a dense liquid. The mineral is black by reflected, and brown by transmitted, light and shows marked absorption. The hardness is between 5 and 6, the specific gravity, at 17·5° C., 3·159, and there is a well-defined prismatic cleavage. The composition is given under I, while under II is given that of a similar amphibole from the essexite of Mount Johnson, analyzed by Mr. Nevil Norton Evans of this university :—

	I	II
Silica	39·23	38·63
Titanium dioxide	4·53	5·04
Alumina	14·38	11·97
Ferric oxide	2·92	3·90
Ferrous oxide	8·56	11·52
Manganous oxide	0·65	0·73
Lime	11·70	12·81
Magnesia	13·01	10·20
Soda	3·05	3·14
Potash	0·98	1·49
Water	0·36	·33
	99·37	99·76

* Quoted by Hintze in his "Mineralogie," p. 1239.

Neither mineral was examined for fluorine.

The similarity in composition of these minerals from eruptive masses twenty-five miles apart is striking and so is the general resemblance in composition to the "basaltic hornblendes" from a number of European localities as given by Schneider.*

Department of Chemistry and Mineralogy,
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* Zeit. für Kryst. u. Min., xviii, 579, 1891. See also paper by Dr. F. D. Adams, entitled "The Monteregian Hills, a Canadian Petrographical Province," which is about to appear in the Journal of Geology.

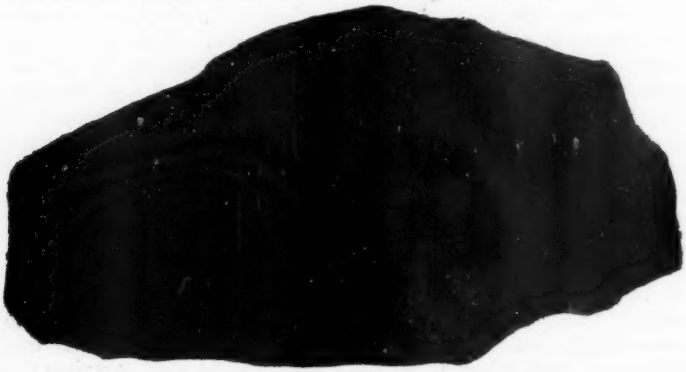
ART. XXXIX. — *The Andover Meteorite;** by HENRY A. WARD.

THE State of Maine has long had three meteorites to its credit: Nobleboro 1823, Castine 1848, Searsmont 1871. All are stones, and all fell in the southern half of the state. We now give first public record to a fourth, also from south of the middle parallel of the state, and also an aerolite. We owe the first knowledge of this to Mr. Henry V. Poor, of Brookline, Mass., the present owner of the mass. This gentleman obtained the specimen from the original owner, on whose farm, adjacent to his summer residence in Andover, Oxford Co., Maine, it fell. Mr. Poor, with great liberality, placed it at my disposition for examination and description. I further received a letter from Mr. Lincoln Dresser, of Andover, who tells the whole story of its fall. Mr. Dresser says, "The meteor that fell near my house on the morning of Aug. 5th, 1898, was witnessed by me, and I was within 25 feet of it when it came down. It came from the northwest at an angle of 75 degrees, and in all probability came from the constellation of Perseus (!). It was accompanied by a loud noise resembling a buzz saw, and had a following of smoke. It was in intense heat when it struck a stone in the wall, grazing the stone. In its fall it passed down through the branches of an elm tree, cutting many of them off as cleanly as if done by a sharp knife. I supposed at the time it was a gaseous ball of fire, and thought it exploded, but after examination I found where it imbedded itself in the earth to the depth of $2\frac{1}{2}$ feet. I secured, by digging, a large piece weighing $7\frac{1}{2}$ lbs., and two or three small ones which were broken by its striking the rock fence. The large piece was irregular in shape and had the appearance of having exploded in the air, as a large piece was lost from one side before it went into the ground. The crust of this one on three sides had a blackened surface with shallow dents, like finger points. The broken part shows a gray rock, looking like silver. The break was fresh, and on exposure to the air you could observe the iron coloring in it. It was of the finest of granite. People in the adjoining towns heard the peculiar buzzing noise, and heard a loud report, probably when it burst."

In June, of the present year, I had the privilege of visiting the spot in Andover where the stone fell. A sharp dent in the granite wall still shows freshly where the stone struck at its first impact. In falling it had passed through thickly set, small branches of an elm tree directly above. Mr. Dresser

* Read before the Rochester Academy of Science, November 10, 1902.

tells me that it was seeing these branches fall, cut off by the stone, which had changed his first instant's impression that the latter was of a gaseous character. By the aid of a ladder and a saw I obtained the portion of a branch two inches in diameter, half cut through by the meteorite. I also obtained two small pieces of the stone itself, one from Mr. Dresser, and another from Mr. E. M. Bailey, also a resident of Andover. Through the kind favor of Mr. Poor I am able to here present a cut of the large mass, which weighs about 6½ lbs.



Andover Aerolite; about three-fifths actual size.

In general shape it is an irregular lengthened polygon like a flattened triangle, with the three points largely truncated. The cut presents one side whose largest dimensions are 7¾ inches in length by 4 inches in greatest breadth. The opposite side, which was broken off in the fall, is of the same length, but 5½ inches in the measure at right angles. All other sides are well coated with a brownish black crust, relieved by occasional patches of lighter brown. The crust is roughened by little, slightly raised pimples, often connected with very short ridges, of the molten matter. On several sides are shallow pittings as large as the impressions of finger-ends. Some of these are separated, others confluent, the latter, as is to be expected, all on the same side of the mass, having their depressed rim in the same direction or aspect. The broken side of the mass shows an interior of a light gray color, and is granular, with a few chondri of much darker color. The whole mass is, in a fresh fracture, brilliant with points of nickeliferous iron sparsely interspersed with bronze-colored troilite. I have given the name of Andover to this meteorite from the proximity of its fall to the town of Andover, Oxford Co., Maine.

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ART. XL. — *A Pseudo-Serpentine from Stevens County, Washington;* by F. W. CLARKE.

IN the course of an investigation upon the ornamental stones of Stevens County, Washington, Mr. R. W. Thatcher and Professor Elton Fulmer, of the State Agricultural Experiment Station, examined a supposed serpentine which proved to have quite anomalous composition. To the unaided eye the rock was ordinary serpentine of a typical yellowish green color; it was fairly homogeneous, and capable of receiving a fine polish. Incomplete analyses, however, by both of the above named chemists showed that it was not serpentine, and as I had been consulted with regard to the interpretation of the data, a sample was sent to me for more exhaustive study.

According to Professor S. Shedd of the Washington Agricultural College, who is conducting the investigation, the rock is from the quarry of the United States Marble Company, 12 miles north and west from Valley, a station on the Spokane Falls and Northern Railroad. It outcrops on the face of a high bluff at an elevation of about 4,070 feet above sea level, and forms a wedge-shaped mass cutting across the mountains in a direction 5° west of north. The adjacent rocks are slates, which lie conformably upon a very coarsely crystalline, dark, almost black, magnesian carbonate. The "serpentine" itself varies a good deal in color, and a series of samples in the U. S. National Museum show that the output of the locality is far from uniform. They range from a white carbonate, through various intermediate mixtures of the verde antique type, to material which appears to be ordinary serpentine. The latter, however, as shown by the serpentine under consideration, is distinctly laminated in structure, and exhibits a splintery fracture. An analysis by Mr. George Steiger gave the following results:

SiO_2	13·08	H_2O at 100°	·85
Al_2O_3	1·63	H_2O at above 100°	23·94
Fe_2O_3	1·25	CO_2	2·03
FeO	·19		
MgO	56·44		99·74
CaO	·33		

These figures at once suggest a probable admixture of brucite with the serpentinous material, and a microscopic examination by Mr. J. S. Diller tends to confirm this supposition.

According to Mr. Diller the specimen is mainly composed of three minerals, *a*, *b*, and *c*. The first two have nearly equal indices of refraction, but differ widely in birefringence. The mineral *a* is the most abundant. In transmitted light it is

colorless, but between crossed nicols it exhibits brilliant colors. The mineral *b* is pale green, and intermingled with *a*. Its birefringence yields weak colors, quite characteristic of chlorite. In quantity it is less than one-fourth of *a*.

Mineral *c* is granular, in scattered grains and irregular groups with a high index of refraction and a birefringence which suggests a carbonate, but it does not effervesce with a dilute acid. It amounts to not more than 5 per cent of the whole. Mineral *b* is certainly chlorite, and *a* may be brucite or possibly serpentine.

By applying Mr. Diller's observations to the analysis of the rock, the proximate composition of the latter may be deduced; although certain assumptions must be made. The carbonate present is probably hydromagnesite, for that species is a frequent associate of brucite. The composition of the chlorite is unknown, but it may be interpreted as essentially clinochlore, and proportional to the ferric oxide and alumina. So much assumed, the analysis gives the following approximate results expressing the composition of the specimen:

Hydromagnesite	5·0	Extraneous water	1·0
Chlorite	14·0		
Serpentine	20·0		100·0
Brucite	60·0		

In this, four minerals appear instead of three, but the microscopic examination did not attempt to discriminate between the brucite and the serpentine.

In order to obtain evidence confirmatory of the foregoing conclusions, a few experiments were made, tending towards fractional determinations. Upon digesting the powdered rock for two hours with cold, dilute nitric acid (10 per cent by volume), 1·32 per cent of Fe_2O_3 + Al_2O_3 and 47·29 per cent MgO went into solution. In a similar experiment with cold, 20 per cent acetic acid, 0·69 Fe_2O_3 + Al_2O_3 and 45·64 MgO were extracted. Brucite dissolves readily in acids of the indicated strength, but some chlorite was evidently attacked as well. I also found that ordinary serpentine was quite appreciably acted upon by weak acetic acid. These experiments then merely show that the rock contains a large amount of magnesium in a very easily soluble condition, the quantity equivalent to 60 per cent of brucite being 41·4. The results are in harmony with the conclusions already reached, and help to support them, although accurate fractional determinations can not be made. The rock is unusual in character, and if the sample examined is fairly characteristic of the entire deposit, the latter should be carefully studied in reference to its origin and its geological relations.

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Art. XLI.—*Studies of Eocene Mammalia in the Marsh Collection, Peabody Museum;* by J. L. Wortman.

[Continued from p. 176.]

Classification of the Primates.

In dividing this order into its primary branches, the first and most necessary step is to obtain, if possible, a clear and comprehensive understanding of the essential or fundamental features which characterize the several lines upon the basis of their evolution. It is naturally to be expected, that, as we approach the point of common origin, these features will become less and less accentuated, and those characters which in the final development have become most pronounced, will be found to be inconspicuous and apparently of little significance in the beginning.

It should be also remembered, that, while some of the phyla have progressed along the lines of their final development with comparative rapidity, and have modified many of the characters which were more or less common to all Primates in the earlier stages of their history, others have retained the primitive features to a greater or less extent. Thus, the presence of such characters as an increased number of premolars, the tritubercular condition of the molars, the small size of the cerebral lobes, with the greater or less development of their several parts, the presence of a floccular fossa of the skull, a third trochanter of the femur, or an entepicondylar foramen of the humerus, the possession of claws instead of nails on the terminal phalanges, as well as many other similar characters, are to be looked upon as common primitive features which characterize all early Primates. Any one of the phyla may have separately and independently modified these features according to the requirements of a new environment.

As an example in illustration of this statement, one might meet with a Primate in which the premolars were much reduced in number, in which the molars were fully quadritubercular, the face much shortened, the brain highly developed, the temporal and orbital fossæ separated by a bony plate; in short, in which might be found many of the characters of the most highly developed Primates; but if, at the same time, the specimen exhibited the peculiarities of the incisors, canines, and the caniniform lower premolar, as well as the cerebral circulation characteristic of the lemurs, one could be perfectly certain that the species was genetically related to and belonged in the Lemuroidea and was not a

member of the Anthropoidea.* We therefore finally come to learn what the essential or fundamental characters really are, and in proportion as our knowledge increases in this direction, in just that proportion shall we be able not only to arrange the species, genera, families, etc., in their true and proper relations to each other, but at the same time may feel assured that such an arrangement represents something more than a mere convenience.

As long as we hold fast to the old horizontal system, our classification will be artificial and unsatisfactory. This is nevertheless ofttimes necessitated by our lack of knowledge, but whenever evidence from the extinct forms is to be had, sufficient to furnish even an incomplete glimpse at the phyletic history, we shall always obtain much more satisfactory results by arranging our classification accordingly. It is by reason of this increase in our knowledge of extinct forms that frequent innovations are necessary, in order to give some expression to the general affiliations which the new discoveries reveal. Our knowledge of the more exact relationships of the various representatives of the Primates is still far from complete, yet I am persuaded that a considerable advance over the older conceptions is now not only possible but urgently demanded. The classification herein proposed introduces some novel features, which may or may not stand the test and be justified by future discovery, but it none the less denotes an effort to give expression to some of the genetic affinities of the several known types of the order, which a study of the extinct forms reveals.

It has been customary to include among the Primates the North American Hyopsodidæ, a small family containing two genera and some four or five species, which are limited in their vertical distribution to the Middle and Upper Eocene strata. Hitherto, nothing has been known of the skeleton, and consequently they have been placed in various positions within the order. In the skull, of which a fairly complete specimen was found by me in the Washakie Basin, Wyoming, in 1895, and is now preserved in the collections of the American Museum, there is no ossified tympanic bulla, and the carotid canal enters the cranium as in the Insectivora. The *foramen ovale* is placed well within the alisphenoid, and is not a notch

* Such an example was, in fact, an actual occurrence. Dr. Forsyth Major discovered an extinct Primate in Madagascar, which he named *Nesopithecus*. From the unusually high development of the skull, and its many resemblances to the higher apes, he concluded that it was an Anthropoid. Lydekker, however, justly criticised this view, and pointed out that, owing to the distinctly lemurine character of the incisors and the caniniform enlargement of the first lower premolar, it should be classed as a highly developed Lemuroid.

in its posterior border completed by the periotic, as is so frequently, if not universally, the case in the lemurs. The incisors are three above and below, and the lachrymal canal is located within the orbit. Although not positively known, it is probable that the lachrymal did not have an extraorbital extension. The pattern of the molars is unlike that of any known Primate, but in many respects is like that of certain primitive Ungulates. From several fragmentary skeletons in the Marsh collection, I am now fortunately able to state that the limbs were totally unlike those of the Primates. In the presence of a supertrochlear foramen, the humerus differs from that of any known Primate. The metapodials do not display the typical globular heads of those of the Primates, but are depressed and strongly keeled at their distal ends. The phalanges are short and stout, and give to the foot a distinctly terrestrial rather than an arboreal character; and, lastly, may be noted the very important character of a completely nonopposable hallux. The North American Hyopsodidæ do not, in fact, possess a single Primate feature, as far as can be discovered, but on the contrary are much more like the Insectivora, to which order I refer them. A summary of the foregoing characters, in which they differ from typical Primates, may be given as follows:

(1) There are three incisors above and below; (2) there is no ossified tympanic bulla; (3) the structure of the molars is not like that of the Primates; (4) the entocarotid circulation is like that of the Insectivora; (5) the limb bones differ from those of any known Primate; (6) the metapodials are not Primate; (7) the phalanges are short; and (8) the hallux is not opposable.

It would appear from the evidence obtained that there are no less than three distinct primary divisions of the order now known, and as these represent as many subordinal groups, the Primates have accordingly been divided into three sections.

The first group which is deserving of a subordinal rank among the Primates, although not commonly admitted, is that represented by the living Aye Aye of Madagascar. Along with this go the American Eocene genera *Mixodectes*, *Cynodontomys*, *Microsyops*, *Smilodectes*, and *Metacheiromys*. The most distinctive and important features of this group consist in the enlargement of the central pair of incisors, the limitation of the enamel to their anterior faces in the later forms, in consequence of which they wear into chisel-shaped points, and, finally, their growth from persistent pulps. Concomitantly, the outer incisors and canines disappear, and the mandibular condyles as well as the glenoid fossæ become modified and adapted to a longitudinal, instead of a vertical

movement of the lower jaw, as in the Rodentia. The entocarotid circulation in *Cheiromys* is like that of the lemurs; the lachrymals are large, with extraorbital extension, and the external opening of the lachrymal canal is outside of the orbit. As in the lemurs, the lachrymal and malar are in contact. *Cheiromys* also agrees with the lemurs in having the fourth digit of the manus the longest of the series, and, except for the hallux, the terminal phalanges are clawlike. In all, there is a well-ossified tympanic bulla, and the limbs and feet are elongate and fully adapted to arboreal life.

Owing to the wide separation both in time and space, it has been doubted whether there is any genetic connection between the aberrant Madagascar species and the extinct North American forms. Indeed, Osborn has recently placed the American series in a primitive suborder of the Rodentia, which he calls the Proglires. After a careful investigation of the evidence, I do not hesitate to state it as my belief that the Madagascar and American forms are intimately related. There can be no two opinions respecting the Primate affinities of *Cheiromys*. This has long since been settled beyond all dispute, and although but comparatively little of the skeleton of the American species is known, what is known betrays the same Primate stamp with equal distinctness. In the New World forms, we have the following conditions presented: Ancient primitive Primates undergoing a rodent-like modification of the central pair of incisors, together with the disappearance of the outer pair and the canines. In American genera, the process is progressive but incomplete, while in the living Madagascar species the modification is complete. No stronger general argument, it seems to me, could be put forth in favor of their relationship, especially when it is remembered that these are the only representatives of the Primates in which the slightest tendency toward such modification is shown. That so distinctive and profound a change could have originated twice independently, in the same order, is so highly improbable as to be unworthy of serious consideration. That the group is of pre-Tertiary origin is shown by the fact that *Mixodectes*, its oldest representative, is already highly modified in the Torrejon or second stage of the Lower Eocene. I propose for the suborder the slightly modified term Cheiromyoidea.

The second suborder of the Primates includes the lemurs, a group which has long been recognized by zoologists as constituting a primary division of the order. Some authorities are inclined to deny the genetic connection of this group, as well as that of the Cheiromyoidea, with the true monkeys, and assign to them a separate and independent ordinal rank. This,

however, is manifestly incorrect, as all the evidence from both living and extinct forms tends to show.

Their chief characters derived from the skeleton are the following: Like the preceding group, the main entocarotid does not enter the tympanic chamber; the lower incisors and canines, when present, are much compressed laterally, elongate, and procumbent in position; the first lower premolar is commonly enlarged, and functions as a canine; there is a well-ossified tympanic bulla; the fourth digit of the manus is the longest of the series; the lachrymal is very generally enlarged, with extraorbital extension, and the external opening of the lachrymal canal is always upon the outside of the orbit;* the lachrymal and malar are nearly always in contact.

Just what value is to be attached to the placentation, in estimating affinities, is a question difficult to decide, but it is believed, and strongly argued by some, that the lowly organized structures and generalized condition by means of which the fœtal envelopes develop a connection with the lining membrane of the uterine walls during gestation furnish a sufficient reason for removing the lemurs widely from the monkeys. In like manner, the rudimentary condition of the posterior cornu and hippocampus minor of the cerebrum, as well as the convolution of the transverse colon, have been looked upon as characters of great significance in classification. While it is probably true that these characters derived from the soft anatomy indicate a wide distinction between existing monkeys and lemurs, yet it is much to be doubted whether these distinctions would not assume very small proportions, or completely disappear, did we have an Eocene monkey with which to make the comparison.

Touching the question of the value of the manner of placentation as applied to the classification of the Mammalia, it is well to recall the words of Flower and Lydekker on this topic. In speaking of the "deciduate" and "non-deciduate" varieties of placenta, they say:† "It was once thought that the distinction between those two forms of placentation is so important as to constitute a sufficiently valid basis for a primary division of the placental mammals into two groups. It has, however, been shown that the distinction is one rather of degree than of kind, as intermediate conditions may exist, and it is probable that in different primary groups the simpler, non-deciduate form may have become developed independently into one or other of the more complex kinds. * * * * * We may conclude

* An exception to this last statement is found in the extinct Malagassy lemur *Nesopithecus* of Forsyth Major. In this species, according to its describer, both the lachrymal and the lachrymal opening are within the orbit.

† Mammals, Living and Extinct, 1891, p. 80.

that, although the characters and arrangement of the fœtal structures may not have that extreme importance which has been attributed to them by some zoologists, they will form, especially when more completely understood, valuable aids in the study of the natural affinities and evolution of the Mammalia."

In view of the important fact that the soft anatomy of extinct forms is wholly inaccessible and will remain forever hidden from us, and furthermore, not knowing exactly what value to attach to characters derived from this source among living forms, it seems by far the safest plan to rely largely, if not solely, upon osteological evidence for our conclusions respecting the affinities and evolution of the various groups of the Mammalia. The facts afforded by the skeleton are the only ones whereby we are permitted to make a direct comparison between the structure of living and extinct forms, and should, therefore, always be ranked as of the first importance.

The following are the chief primitive characters of the lemuroid skeleton: The cranial cavity is proportionately small; the face is generally large and elongate in comparison with the size of the brain case; the temporal and orbital fossæ are not separated by a bony plate (except in *Nesopithecus*); the zygomata are usually broad and heavy, and the malar frequently extends beneath the zygomatic process of the squamosal to near the glenoid fossa, as in the Marsupials; the malar articulates with the lachrymal in front in many species, thereby shutting out the maxillary from a share in the anterior or lower rim of the orbit; there is usually a considerable interorbital breadth; the squamosal has little vertical expansion on the side wall of the skull; there are nearly always large postglenoid foramina; the posterior free edge of the hard palate is thickened; the molars are for the most part tritubercular; the atlas has separate openings for the two divisions of the suboccipital nerve; the ilium is generally little expanded; the head of the femur is more or less sessile upon the shaft; the digital fossa has a slitlike form; the second trochanter is large and internal in position, and there is always a third trochanter; the proximal plantar extremity of the metatarsal of the hallux, for the attachment of the long peroneal tendon, is enlarged and prolonged; the second digit of the pes bears a terminal claw, and the humerus has an entepicondylar foramen.

It is at present difficult to decide just how many families should be recognized in this suborder. A conservative estimate would not place them above two or perhaps three. Of these, the living species would constitute one, the Lemuridæ; the extinct Malagassy *Nesopithecus* a second, the Nesopithecidæ, and very doubtfully the extinct *Megaladapis* a third, the

Megaladapidæ. It should be remembered, however, that the Lemuridæ, as thus constituted, include forms of very diverse structure and probably not very closely related. Thus the Indrisinæ, usually considered as one of the best-marked and most distinct subfamilies, in the absence of one pair of incisors or canines in the lower jaw, together with the strongly developed mesostyle of the superior molars, appear to be sufficiently differentiated from the central forms of the typical lemurs to be entitled to a distinct family rank.

The third and last primary division of the order is the Anthropoidea, and in the present state of our knowledge it seems quite impossible to obtain any very clear insight into the phyletic history of the various groups composing it. Until much additional information is secured concerning many of the fossil types already known, as well as of the large number of undiscovered connecting forms which must have certainly existed, any attempts at a classification that may be regarded as final can not at present be made. Still, certain advance steps may, I think, now be taken, which will help considerably toward a final solution of some of the many difficult problems involved in unraveling the tangled web of simian evolution.

The characters by means of which the members of the group are distinguished from the two foregoing suborders are as follows: Incisors reduced to two pairs above and below (in *Tarsius*, one below); they have a normal form and position; there is no caniniform enlargement of the first lower premolar; the entocarotids traverse the petro-tympanic; the lachrymal canal (except in one group) is more or less confined within the orbit, and the facial part of the bone is quite generally reduced; the lachrymal and malar are not in contact, leaving the maxillary a share in forming the anterior rim of the orbit; the fourth digit of the manus is never the longest of the series.

It would appear from present evidence that the Anthropoidea early divided into at least three main branches, but the exact lines of descent from these starting points can not now be traced with any degree of certainty, among the majority of the living species. The first of these divisions is represented by the living marmosets, a group which Huxley classified under the name of the Arctopithecini.* Their chief claim to distinction consists in the lack of opposability of the hallux and pollex; the clawed condition of all the terminal phalanges of both manus and pes, except a slight flattening of that of the hallux; the loss of the third molar above and below, and the tritubercular condition of the superior molars. These characters, except the last, are unique among the Primates, and may or may not indicate a very ancient branching from the main

* Anatomy of Vertebrated Animals, 1872, p. 392.

axis. Whatever classification is finally adopted, it seems to me that this should be regarded as one of the primary divisions of the suborder, since the characters of the extremities are not found in any other member of the order thus far known.

In the second division of the Anthropoidea, I included *Tarsius* and its allies. It has been customary with nearly all authorities to classify this species in the Lemuroidea, assigning to it the rank of a separate and distinct family. Hubrecht,* however, from a careful study of its placentation has shown that in this respect it is widely different from the lemurs and decidedly like the monkeys. Hence, he has proposed its removal to the Anthropoidea. In confirmation of this view, it may be added that the entocarotid circulation, which I am inclined to regard as of fundamental importance, is analogous to that of the primitive monkeys and not like that of any of the lemurs. Similarly, the lack of union between the malar and lachrymal is found in all the monkeys, and the reverse condition in the lemurs. The teeth do not exhibit that peculiar modification seen in all lemurs, but again are like those of the monkeys; and, lastly, the fourth digit of the manus is not the longest of the series as in all the lemurs, but is shorter than the third as in the monkeys. Thus, it will be seen that the evidence derived from five independent sets of organs, the placentation, lachrymo-malar union, entocarotid circulation, dentition, and digital lengths of the manus, all concur in assigning to *Tarsius* a position with the monkeys and not with the lemurs. On the other hand, it may be stated that in the extraorbital extension of the lachrymal and the location of the external openings of the lachrymal canal outside the rim of the orbit, it agrees with the lemurs.

This question of the lachrymal region in the skull of the Primates has recently formed the subject of extensive and painstaking research by Forsyth Major.† From his investigations, we learn that, with the single exception of *Nesopithecus*, a highly developed extinct type from Madagascar, all the lemurs possess an enlarged lachrymal which reaches beyond the orbit, while the external opening of the lachrymal canal is situated upon the side of the face. In some species, notably *Loris*, no lachrymal was found, but there can be little doubt that its absence is due to early fusion with the maxillary and complete obliteration of the sutures, as in the sea-lions and seals. Another interesting observation recorded by Dr. Major relates to the lachrymal enlargement seen in certain South

* Die Keimblase von Tarsius. Festschrift für Carl Gegenbaur, Leipzig, 1896. The Descent of the Primates, Princeton Lecture, 1897.

† On Some Characters of the Skull in Lemurs and Monkeys, Proc. Zool. Soc. London, February, 1901.

American apes, as the howlers and woolly spiders, wherein it is impossible to decide whether the lachrymal canal can be said to be within or without the orbit. In view of these transitional conditions, the great taxonomic significance of the position of the lachrymal canal, which it was formerly thought to possess, is materially weakened. The large lachrymal with the opening of the canal extraorbital in position is undoubtedly the primitive condition. This is demonstrated by reference to the Marsupials, in some of which, notably *Myrmecobius*, it is unusually large and sends a considerable spur outward upon the zygoma to join the malar. In all Insectivora, Rodentia, and primitive Carnivora, the enlarged lachrymal as well as the extraorbital position of the canal, is, as far as I am aware, universal.

For views in favor of retaining *Tarsius* in the Lemuroidea, as well as for a general discussion of the genetic relationship of the latter to the Anthropoidea, I refer the reader to the excellent papers by Mr. Charles Earle.*

If *Tarsius* is a member of the suborder Anthropoidea, of which in my judgment there can be little question, then it appears equally certain that, with its allies, it represents an independent branch from the main axis, and one, moreover, of equal rank with the Arctopithecini, or marmosets, since its primitive lachrymal arrangement associated with precocious tooth reduction, as well as with some peculiarities of the pterygoid region, mark it off distinctly as a side branch. I suggest for this group, therefore, the name Paleopithecini.

Of the extinct American types, *Euryacodon* and *Anaptomorphus* are names which probably refer to one and the same genus. The skull structure of the best-known species, *Anaptomorphus* or *Euryacodon homunculus*, was described by Cope from an exceptionally fine specimen found by me in the Wasatch bed of the Big Horn Valley, Wyoming, in 1881. This specimen has recently been refigured by Osborn.† Its resemblance to *Tarsius* is so striking that there can be apparently no question whatever of the near relationship of the two. This is seen in the following important characters: The entocarotid canal traverses the tympanic chamber, and its external orifice is situated as in *Tarsius;* the malar does not unite with the lachrymal; the lachrymal is relatively large and extends out upon the face; the external opening of the lachrymal canal is extraorbital in position; the auditory bullæ are much inflated and the external alæ of the pterygoids extend outward and backward in such a manner as more or less to enclose the bullæ; the structure of the teeth

* Science, February 12, 1897; and May, 1897. American Naturalist, July and August, 1897.

† American Eocene Primates, Bull. Amer. Mus. Nat. Hist., June, 1902.

resembles that of *Tarsius* very closely, and the premolars in the Bridger species at least are reduced to two; there is no lemurine modification of the incisors or first lower premolar; the brain is relatively large, and the face is considerably bent down on the basicranial axis, as in *Tarsius;* while, lastly, the species are small and the orbital cavities enlarged.

From this striking array of similarities which Cope was careful to point out, I am fully convinced that the two forms are closely related and should be placed in the same group. In like manner, we may feel reasonably certain in arranging the extinct European *Necrolemur* of Filhol in the same group. Although the skull characters are less perfectly known than in the American species, yet the lachrymal region, the dentition, and the general appearance of the single skull known, all betray the same fundamental resemblances to *Tarsius* noted in *Anaptomorphus* or *Euryacodon*. I do not hesitate, therefore, to classify it with this series. The same may also be true of the imperfectly known *Microchœrus* of the European Eocene, but this is not at all certain. There is some evidence that the latter genus is closely related to and represents *Hyopsodus* in Europe.

The position of the remaining American genera, *Omomys*, *Hemiacodon*, and *Washakius*, is more problematical. No complete skull of any of these forms is known, and it is impossible to say whether they most resemble *Tarsius* or the monkeys. In one species, *Hemiacodon gracilis*, a fragment of the maxillary is sufficiently preserved to show that there was no union between the malar and lachrymal. The incisors do not display any lemurine characteristic and the inference is tolerably clear that they belong either with the Paleopithecini or with the true monkeys. I may add just here that there is such a marked resemblance between the teeth of *Omomys* and those of certain of the living South American Cebidæ, that I am strongly inclined to the belief that these extinct forms are true monkeys.

There yet remains to be discussed another group of extinct Primates whose remains are better preserved, and hence more completely known, than any others yet discovered in the Eocene, the Adapidæ of Europe and the so-called Notharctidæ of America. Cope* arranged them in the group Mesodonta, which he made a suborder of his order Bunotheria. He included in the Bunotheria the suborders Creodonta, Mesodonta, Insectivora, Tillodontia, and Tæniodonta, at the same time holding that the Prosimiæ, or Lemuroidea, should be placed here as well. He seems to have entertained the opinion that all were ordinally distinct from the Quadrumana, or Primates, although

*Tertiary Vertebrata, 1884.

he does not state this directly. He defined the Mesodonta as follows: "Incisors not growing from persistent pulps; molars tubercular, never sectorial; third trochanter elevated; astragalus not grooved above." Under the head of Prosimiæ, he further adds, "The suborder may be differentiated from the Mesodonta by the possession of an opposable hallux of the posterior foot," but qualifies this definition with the statement that the lack of opposability of the hallux is not demonstrated in any of the species except *Pelycodus*.

There seems to be a great deal of confusion in Cope's statements regarding the classification of the genera under the Mesodonta and Prosimiæ. In the Mesodonta, he classified the following genera: *Omomys*, *Microsyops*, *Pantolestes*, *Tomitherium*, *Pelycodus*, *Sarcolemur*, *Hyopsodus*, *Aphelicus*, *Adapis*, and *Opisthotomus*. In the Prosimiæ, on the other hand, he included three families, viz.; Adapidæ (genera not stated), Mixodectidæ comprising the genera *Mixodectes*, *Microsyops*, and *Cynodontomys*, and the Anaptomorphidæ including *Anaptomorphus* and *Necrolemur*. It will be thus seen that several of the genera are referred to both suborders.

The next authority of note to contribute to this subject is Schlosser. He regarded all these early extinct forms as constituting a group equal in rank to that of the Lemuroidea and Anthropoidea, and one from which these two, in all probability, have been derived. This group he named the Pseudolemuroidea. Osborn in his recent paper, "American Eocene Primates,"* inclines apparently to the same view. He says: "Three suppositions are possible: First, that these Primates represent an ancient and generalized group (Mesodonta, Cope) ancestral to both Lemuroidea and Anthropoidea; second, that they include representatives of both Lemuroidea and Anthropoidea, contemporaneous and intermingled; third, that they belong exclusively to one or the other order. There are certain advantages in the revival of the term Mesodonta Cope, a suborder (anticipating the terms Pseudolemuroidea and Tarsii) which would bear somewhat the same relationship to the modern specialized Monkeys and Lemurs that the Condylarthra bear to the Ungulata and the Creodonta to the Carnivora."

As regards the validity of the group Mesodonta of Cope and its suggested revival by Osborn, very little need be said. From the most abundant skeletal materials of both *Adapis* and *Notharctus* we now know that the hallux was almost if not quite as opposable as in any living Primate. Cope's statement, therefore, of its lack of opposability in *Pelycodus*, a genus scarcely distinct from *Notharctus*, must with almost absolute

* Loc. cit.

certainty be erroneous. His technical definition of the group, moreover, as well as its dissociation from the Primates, I regard as utterly unsound, illogical, and in no wise warranted by the facts. I do not believe that any such natural group exists, and a revival of the name Mesodonta can result only in confusion. As we have already seen, there are types of very different affinities among these ancient Primates, and this fact in my judgment effectually precludes the possibility of their association into a single group. What position, then, do *Adapis* and *Notharctus* occupy with reference to these natural groups already outlined? That they can not be consistently placed in the Lemuroidea is evident for the following reasons: The incisors do not exhibit any traces of lemurine modification, but, on the contrary, are like those in typical monkeys; the main entocarotid canal traverses the petro-tympanic chamber as in *Tarsius;* the lachrymal and malar do not unite on the anterior rim of the orbit; the digital lengths of the manus are not known with certainty, but in *Notharctus*, the evidence is reasonably conclusive that the fourth was not longer than the third.

On the other hand, their resemblance to the Paleopithecini is more marked. This is seen in the greatly inflated condition of the tympanic bullæ as well as in the outward and backward extension of the external alæ of the pterygoids. These forms differ from the Paleopithecini, however, in having a more reduced lachrymal, in the position of the external opening of the lachrymal canal on or near the rim of the orbit, in having a greater number of premolars, and in general in being larger and of more robust proportions. Thus, it will be seen that they occupy a position intermediate in many respects between the remaining Anthropoidea and the Paleopithecini. In the latter, there seems to have been a marked tendency toward precocious specialization in both tooth reduction and brain enlargement, which are curiously associated with retention of the primitive condition of the lachrymal. *Adapis* and *Notharctus*, on the other hand, exhibit advance in the reduction of the lachrymals, but retain the more generalized features of the dentition and brain enlargement. These are the essential differences between the two lines and mark out very distinctly the trend as well as the possibilities of their future development. It is in just such a group as that which includes *Adapis*, *Notharctus*, and *Limnotherium*, that we must seek for the beginnings of the higher monkeys and apes which follow; and while these species, at present the only well-known types of the series, may not have been in the direct line of descent, they can not at the same time have been far removed from it. *Omomys* and *Washakius*,

as far at least as we are permitted to judge from their scant remains, are closely related to *Adapis* and *Notharctus*, but had made greater progress in the reduction of the premolars. This gives an especially monkey-like appearance, pointing particularly in the direction of certain living Cebidæ. It is probable, therefore, that all this series should be classified as primitive members of a third section of the Anthropoidea. If this last division represents a homogeneous and natural group, equivalent in rank to that of the Arctopithecini and Paleopithecini, it is deserving of a name, and I suggest for it that of Neopithecini.

A summary of the foregoing discussion of the classification of the Primates, together with the more technical definitions of the several groups, is embodied in the following statement:

Limbs elongate, with prehensile manus, and pes fully adapted to an arboreal life; incisors enlarged and in later forms becoming reduced in number and rodent-like in pattern; canines disappearing in later forms; an ossified tympanic bulla; entocarotid circulation as in the Galaginæ and Lorisinæ; three families, Microsyopsidæ, Metacheiromyidæ, and Cheiromyidæ.
Cheiromyoidea.

Limbs elongate, prehensile, and adapted to an arboreal habit; incisors of lower jaw reduced in size, pectinate, and proclivous in position; anterior lower premolar very generally enlarged and functioning as a canine; entocarotid canal not traversing the petro-tympanic; malar and lachrymal very generally in contact on anterior rim of orbit; fourth digit of the manus the longest of the series; three families, Lemuridæ, Indrisidæ, and Nesopithecidæ.
Lemuroidea.

Limbs elongate, extremities prehensile, and fully adapted to an arboreal life; incisors and canines normal in form and position; entocarotid traversing petro-tympanic; malar and lachrymal not in contact on anterior rim of orbit; fourth digit of manus shorter than third; three superfamilies or groups, Arctopithecini, Paleopithecini, and Neopithecini.
Anthropoidea.

The definitions and divisions of the superfamilies of the Anthropoidea are as follows:

Hallux and pollex of manus and pes not opposable; true molars reduced to two in each jaw; one family, Hapalidæ.
Arctopithecini.

Hallux and pollex fully opposable; three true molars; lachrymal enlarged, with well-developed *pars facialis*; lachrymal canal opening without orbit; premolars precociously reduced in highest forms; two families, Anaptomorphidæ and Tarsiidæ.
Paleopithecini.

Hallux and pollex fully opposable; three true molars; lachrymal reduced; lachrymal canal opening on or inside orbital rim; premolars progressively reduced to two in advanced forms; brain enlargement progressively increasing in the later types; five families. Neopithecini.

The Neopithecini are divisible into at least five distinct families of which in the living fauna three are confined to the Old World* and one to the New World. One extinct family is common to the two hemispheres, and as far as can be now ascertained from the remains, occupies a position not far removed from the common primitive stem from which the great majority of the living simian population of the Old and New Worlds originated. In the case of the Old World families, the gap is as yet very wide, but in the case of the New World Cebidæ, the interval is much less, and is not greater than one would be reasonably led to anticipate between an ancestor of Upper Eocene time and a living descendant. In fact, the difference is not nearly as great as it is between the modern horse and its Upper Eocene progenitor, *Orohippus*. As this phase of the subject will be more fully discussed in another section of the present paper, it may be here dismissed.

The families of the Neopithecini are distinguished upon osteological considerations, as follows:

Premolars four above and below; orbital and temporal fossæ more or less freely continuous; parietal uniting with alisphenoid on side wall of cranium; molars more or less fully quadritubercular, with ridges of superior trigon distinct; a large petro-tympanic bulla expanded behind; external auditory meatus not prolonged into a tube; carotid canal piercing bulla near postero-external angle; a postglenoid foramen; muzzle elongate; lachrymal slightly extended beyond rim of orbit, with opening of lachrymal canal upon edge of orbit; ilium little expanded; ischium without distal enlargement or everted edges; head of femur more or less sessile upon shaft; digital fossa of femur narrow and slitlike; a third trochanter and an entepicondylar foramen; hallux fully opposable; metatarsal of hallux with elongate proximal plantar extremity; pollex not as fully opposable as in higher species; foramina of atlas complex. Adapidæ.

Premolars three above and below; orbital and temporal fossæ separated by bony plate; parietal uniting with alisphenoid on side wall of cranium; frontal excluded from contact with alisphenoid by malar on side of skull (except in *Mycetes* and some species of *Ateles*); molars fully quadritubercular, with ridges of superior trigon distinct; first lower premolar without elongate

* In this statement, the origin of man is considered to have taken place in the Old World.

anterior border, as in preceding family; petro-tympanic bulla little expanded behind; no vaginal process; auditory meatus not prolonged into a tube; carotid canal piercing bulla near postero-internal angle; a large floccular fossa on internal surface of periotic; postglenoid foramen present or absent; muzzle abbreviated; lachrymal either slightly extended beyond rim of orbit or confined wholly within it; ilium well expanded; ischium without distal enlargement and edges not everted; head of femur with well-defined neck and an open digital fossa; no third trochanter; an entepicondylar foramen of humerus; hallux fully opposable; metatarsal of hallux without elongate proximal plantar extremity; pollex not as fully opposable as in higher species; foramina of atlas complex. Cebidæ.

Premolars two above and below; orbital and temporal fossæ separated by bony plate; no parieto-sphenoid but a temporo-frontal contact in the side wall of the cranium; frontal and alisphenoid not separated by malar on side wall of cranium; molars fully quadritubercular of squarish outline, without traces of superior trigonal ridges, but tending to the formation of cross crests; first (third) inferior premolar with characteristic elongation of anterior border; petro-tympanic bulla little inflated and filled with cancellous tissue; no vaginal process; auditory meatus prolonged into a bony tube; carotid canal piercing bulla near postero-internal angle; a large floccular fossa on inner surface of periotic; presphenoid and basisphenoid remaining long distinct, as in preceding family; no postglenoid foramen; muzzle abbreviated; lachrymal never reaching rim of orbit, and of much greater vertical than transverse extent; ilium well expanded; ischium with distal enlargement and everted edges; head of femur with well-defined neck and an open digital fossa; no third trochanter; no entepicondylar foramen of humerus; hallux fully opposable; metatarsal of hallux without elongate proximal plantar extremity; pollex fully opposable; foramina of atlas complex or simple. Cercopithecidæ.

Premolars two above and below; canines enlarged and of greater vertical extent than premolars and incisors, as in preceding families; orbital and temporal fossæ distinct; a temporo-frontal contact on side wall of skull (except in Orang); frontal and alisphenoid not separated by malar on side wall of cranium; molars fully quadritubercular, with more or less rounded outline, without any tendency to the formation of transverse crests, but with distinct remains of superior trigonal ridges; first (third) inferior premolar with traces of elongate anterior border (least distinct in Chimpanzee); petro-tympanic bulla little inflated, with a moderately well-developed vaginal process (except in *Hylobates*) and no ossified styloid process as in preceding families; auditory meatus elongate; carotid canal as in Cercopithecidæ; floccular fossa on internal surface of periotic vestigial;

no postglenoid foramen; presphenoid and basisphenoid early coössified; lachrymal confined within the orbit, having a quadrate outline without vertical enlargement (except in *Hylobates*); ilium expanded; ischium with only moderate distal enlargement and without strongly everted edges (except in *Hylobates*); head of femur with well-developed neck and open digital fossa; no third trochanter; no entepicondylar foramen; hallux and metacarpal of hallux as in Cercopithecidæ; pollex fully opposable; sesamoids of flexor tendons of four outer digits in manus and pes vestigial or wanting and keels absent (except in *Hylobates*); foramina of atlas simple; as in the preceding families, the mastoid process is rudimental or wanting and the premaxillo-maxillary suture long persists, being obliterated only in aged specimens; there is no foramen spinosum for the passage of the middle meningeal artery, but a notch in the anterior external part of the foramen ovale apparently represents it in the Gorilla and Chimpanzee; the frontals meet in the middle line over the presphenoid and behind the ethmoid (except in Orang). Simiidæ.

Premolars two above and below; canines reduced and of no greater vertical extent than premolars and incisors; orbital and temporal fossæ distinct; a spheno-parietal contact on the side wall of cranium (variable); frontal and sphenoid not separated by malar on side wall of skull; molars fully quadritubercular with superior trigonal ridges distinct; first (third) inferior premolar without any trace of elongate anterior border; no petrotympanic bulla; but a well-defined vaginal process and a well-ossified and coössified stylohyal; external auditory meatus and carotid canal as in Simiidæ; no postglenoid foramen; no floccular fossa on inner surface of periotic; presphenoid and basisphenoid early coössified; lachrymal confined within the orbit, having a much greater vertical than antero-posterior diameter; distal enlargement of ischium reduced and edges not everted; neck of femur and digital fossa as in Simiidæ; hallux enlarged, not opposable and in line with other digits; keels, grooves, and sesamoids of four outer metapodials of manus and pes absent; foramina of the atlas simple; a well-developed mastoid process; the maxillo-premaxillary suture early obliterated; a distinct foramen spinosum for the passage of the middle meningeal artery; no union of frontals over presphenoid and behind ethmoid. Hominidæ.

[To be continued.]

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *The Atomic Weight of Cæsium.*—An elaborate revision of the atomic weight of cæsium has been made by Richards and Archibald. The material used in this investigation was chiefly a large quantity of cæsium salts from the pollucite of Paris, Maine, which Wells of the Sheffield Scientific School had purified by his method of recrystallizing the salt $CsCl_3I$, and which was so pure that the authors were unable to improve upon its purity. Three methods of atomic weight determination were used; the analysis of the chloride, which consisted in comparing cæsium chloride with silver chloride and with silver; the analysis of cæsium bromide, with analogous comparisons; and the ignition of cæsium nitrate with an excess of pure silica, where cæsium nitrate was compared with N_2O_5. Indirect comparisons with potassium chloride and oxide were also made. The close agreement of the individual results and of the results by the different methods is very remarkable, and there is no doubt that the atomic weight of this rare element is now known with the highest degree of accuracy. As an outcome of forty-two analyses involving seven different ratios and three compounds of cæsium (the chloride, bromide and nitrate), the authors calculate the atomic weight of cæsium to be 132·879, if oxygen is 16. The result shows that the early work done upon this atomic weight in the Sheffield Laboratory by Johnson and Allen, was remarkably exact.—*Proceedings Amer. Acad.*, xxxviii, 443. H. L. W.

2. *Conductivity Produced in Gases by the aid of Ultra-Violet Light.*—In a former paper Professor Townsend confirmed the results previously published by him, on the theory of the genesis of ions by collision. It was shown that the negative ions thus produced in a gas are identical with the negative ions set free from the negative electrode by the action of ultra-violet light. Professor Townsend has now extended his results in experiments with hydrochloric acid gas and water vapor, with the result that the same theory of genesis affords an explanation of the phenomena and we are led to conclude that negative ions are generated in air, carbonic acid gas, hydrogen, water vapor, or hydrochloric acid gas, which are all identical with the negative ions set free from a zinc plate by the action of ultra-violet light. It is shown that a negative ion may pass inside the sphere of action of a molecule without producing new ions.—*Phil. Mag.*, April, 1903, pp. 390–398. J. T.

3. *Absorption of Gravitation Energy by Radio-active Substances.*—H. R. Geigel published in the Ann. der Physik, 10, p. 429, 1903, some results tending to show evidence of this absorption. W. Kaufmann, of the Physik. Inst. d. Univ. Göttingen,

has repeated Geigel's results and finds that they are explained by thermal disturbances in the process of weighing.—*Ann. der Physik*, No. 4, 1903, pp. 894–896. J. T.

4. *Emanations of Phosphorus.*—G. C. SCHMIDT shows that the electron theory does not explain these emanations and concludes that there is no evidence of the production of ions or electrons by the slow oxidization of phosphorus. The conductivity for electricity arising from the emanations is only an apparent one arising from convection by means of the cloudy oxidization products. The conductivity arises from the phosphoric acids.—*Ann. der Physik*, No. 4, 1903, pp. 704–729. J. T.

5. *The Position of Radium in the Periodic System.*—R. RUNGE and J. PRECHT have obtained, by means of the bromide prepared by Herr Giesel, a more perfect spectrum than has hitherto been obtained. It was found that the strongest lines of radium are exactly analogous to the strongest lines of barium and the corresponding lines of the related elements Mg,Ca,Sr. From the behavior of radium vapor in a magnetic field radium is also to be classed with the above elements. The authors call attention to the following conclusions: "In each group of chemically related elements the atomic weight varies as some power of the distance apart of the two lines of a pair"; secondly, "The logarithms of the atomic weights and those of the distances when plotted as coördinates lie on a straight line for a chemically related group of elements." The atomic weight of radium is given as 257·8.—*Physikalische Zeitschrift*, 4 Jahrgang, No. 10, pp. 285–287. J. T.

6. *Charge on the Ion, produced in air by Roentgen Rays.*—HAROLD A. WILSON made a fresh determination of this quantity, after Professor J. J. Thomson's first determinations, and arrived at a result which was half as large as Professor Thomson's. The latter lately has revised his earlier determination and has obtained the same result as Mr. Wilson.—*Phil. Mag.*, April, 1903, pp. 429–441. J. T.

7. *Reversed Lines of Metallic Vapor produced in Narrow Capillaries of Glass or Quartz.*—When terminals of different metals are enclosed in narrow capillaries of quartz or glass one centimeter apart, an interesting series of reactions are obtained with powerful condenser discharges. The easily vaporized metals like cadmium, lead, tin, give both bright and reversed lines. The lines of these metals, which are linear and narrow in the spark spectra in air, broaden out in rarified hydrogen or rarified oxygen to a great extent, depending on the exhaustion and the energy of the discharge. In some cases this broadening is greater toward the red end of the spectrum. No spectrum of iron lines could be obtained in such capillaries: even when the terminals were only three millimeters apart, and the bore of the capillary was one millimeter and a half. Aluminum, however, gave its peculiar spectrum with certain lines reversed. —*Jefferson Physical Laboratory.* J. T.

II. Geology and Natural History.

1. *New Mineral Names.* Brunsvigite, a new Leptochlorite from the Radauthal; J. Fromme. Brunsvigite is found in the gabbro quarry, "Bärenstein IV" on the Schmalenberg in a vein with calcite, quartz, arsenopyrite, chalcopyrite, pyrite, galena and sphalerite. It occurs as thick to fine-leaved masses between the other minerals and also as rounded aggregates in the cavities. Its color is green to dark leek-green and has a gray-green streak. H = 1 – 2; G. = 3·0106. The powder is easily decomposed by acids with the separation of pulverulent silica. The analysis gave the following formula; $6SiO_2$, $2Al_2O_3$, 6FeO, 3MgO, $8H_2O$. —*Min. u. petr. Mitth. 21, 1902, p. 171–177.*

Pyknochlorite, a new chlorite belonging to the clinochlore group. J. Fromme. In the gabbro quarry, "Bärenstein II" on the Schmalenberg occurs a vein formed chiefly of calcite intergrown with quartz. In the interstices between the minerals and binding them together occurs a new chlorite mineral which has been named pyknochlorite. It forms beautiful gray-green solid or micro-crystalline masses. Hardness = 1 – 2, specific gravity = 2·8314. With acids only partially decomposed; before blowpipe yields a black slag. The analysis gives the following formula: $10SiO_2$, $4R_2O_3$, 17RO, $14H_2O$; R^{III} being chiefly Al with a little Fe, R^{II} chiefly Fe and Mg with small amounts of Ca and Mn.—*Min. u. petr. Mitth. 22, 1903, p. 69.*

Liveingite, a new mineral from Binnenthal—R. H. Solly and H. Jackson. The analysis yielded: Pb, 47·58; S, 24·91; As, 26·93; from which the formula, $4PbS.3As_2S_3$, was derived. Liveingite is mon-clinic, $\beta = 89° 45\frac{1}{2}'$.—*Proc. Cambridge Phil. Soc. 1901, 11, 239.*

Serendibite, a new borosilicate from Ceylon—G. T. Prior and A. K. Coomáraswámy. This new species was found near Kandy, Ceylon, in the contact zones between an acid granulite and thin limestone bands. It occurs for the most part in irregular grains of a blue color. Luster is vitreous; fracture, subconchoidal; hardness, $6\frac{3}{4}$; density, 3·42; biaxial, probably triclinic; pleochroism from yellow to blue. The mineral is infusible, unattacked by acids, gives a little water when heated in the closed tube, and when fused with acid potassium sulphate and calcium fluoride gives the green flame of boron. The formula derived from the analysis is: 10 (Fe,Ca,Mg)O, $5Al_2O_3$, $6SiO_2$, B_2O_3.—*The Min. Mag., xiii, p. 224.* W. E. F.

2. *Les Richesses Minérales de L'Afrique;* by L. De Launay. Paris, Ch. Beranger, 1903.—This book describes the ore deposits of Africa as they are known and developed at the present time. An outline of the general geology of the continent is given in the early part of the volume and then follow in order discussions of the gold, copper and iron deposits, to each of which a chapter is devoted. Other chapters deal with the occurrence of the various other metals, with the diamond mines, the phosphate,

salt, coal and petroleum deposits. The book is illustrated by many maps and geological sections. W. E. F.

3. *The Glacial Geology of New Jersey;* by R. D. SALISBURY, assisted by H. B. KÜMMEL, C. E. PEET and G. N. KNAPP. Geol. Survey of New Jersey. Vol. V, 782 pp., 66 pls., 102 figs.—The New Jersey Survey (H. B. Kümmel, State Geologist) has issued a work on glacial geology which is of great educational value. Part I, on The Drift and the Glacial Period, is an ably written text-book on glaciation in general with illustrations taken from New Jersey. Part II treats of local details of glacial action and will be of direct educational and economic value to the people of the State.

4. *The Birds of North and Middle Americas;* by ROBERT RIDGWAY. Part II, Bulletin U. S. National Museum, No. 50. 8vo, 834 pp., 22 plates.—This is a careful and elaborate revision of the families of tanagers, troupials, honey-creepers, and wood-warblers, with analytical keys, descriptions, and synonymy of all the species and subspecies. A. E. V.

5. *A List of North American Lepidoptera and Key to the Literature;* by H. G. DYAR. Bull. U. S. Nat. Mus., No. 52, 723 pp., 1902.—This extensive catalogue includes all the species described, up to date. The serial numbers of the species run up to 6,622, but there are some interpolated. The general distribution and principal synonyms are given. The work gives evidence of an immense amount of careful work, and will be indispensable for all entomologists interested in Lepidoptera. A. E. V.

6. *Synopsis of the Family Veneridæ and of the North American Recent Species;* by W. H. DALL. Proc. U. S. Nat. Museum, xxvi, pp. 335–412, 5 plates.—This contains a careful revision of the genera, subgenera and sections of the Veneridæ, with many changes in the nomenclature, made in accordance with the modern revisions of the rules of nomenclature. A. E. V.

OBITUARY.

PROFESSOR HENRY BARKER HILL, director of the Chemical Laboratory of Harvard College, died on April 6 in his fifty-fourth year.

DR. ALBERT HUNTINGTON CHESTER, professor of chemistry and mineralogy in Rutgers College, died April 13 in his sixtieth year.

Rear-Admiral GEORGE E. BELKNAP, retired, who in addition to eminent services in the navy was in charge of important hydrographic work and was at one time superintendent of the Naval Observatory, died on April 7, at the age of seventy-one years.